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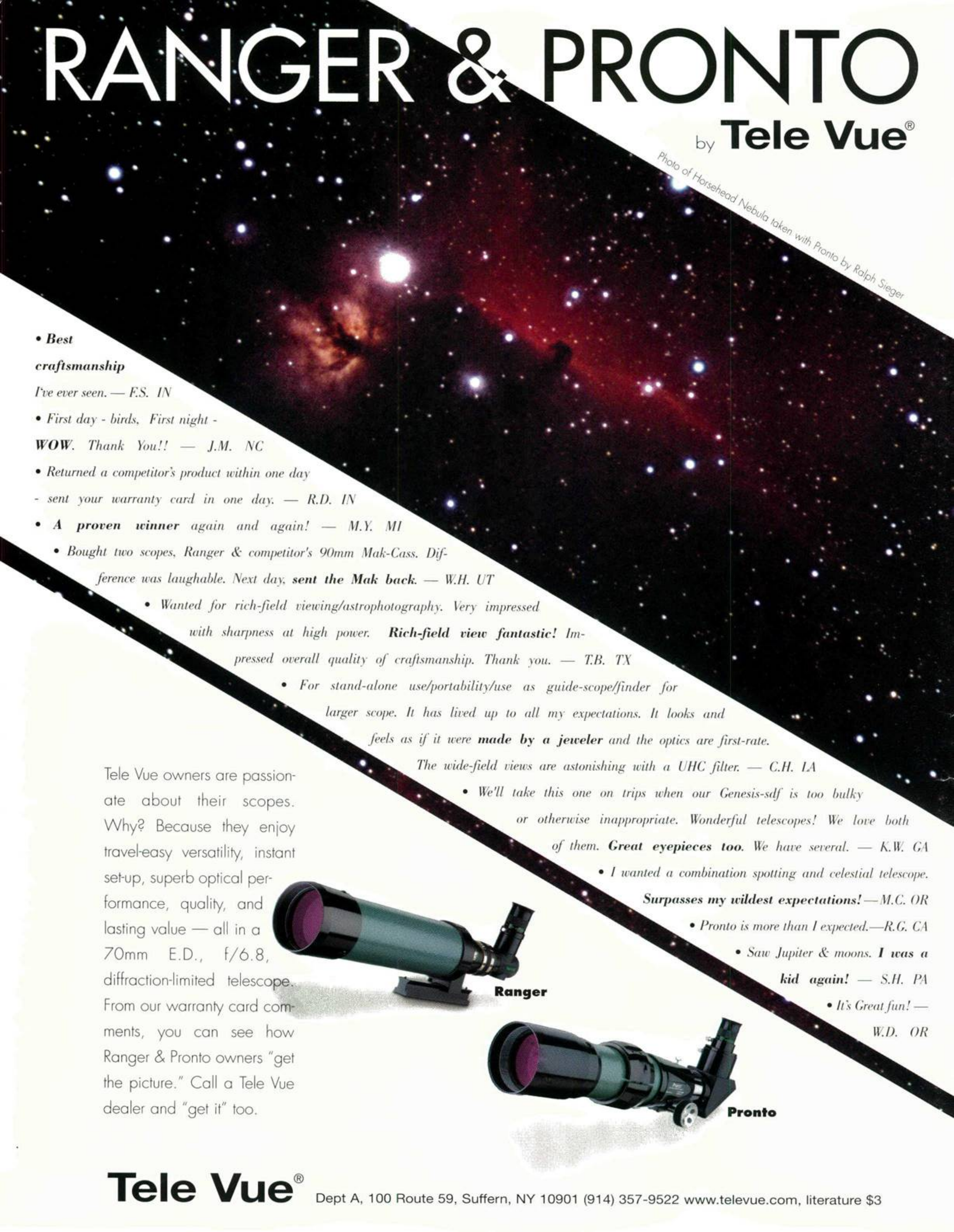

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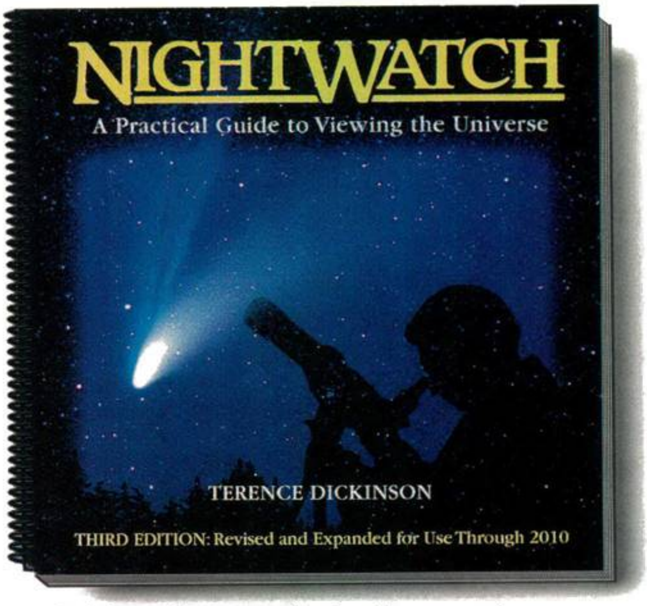
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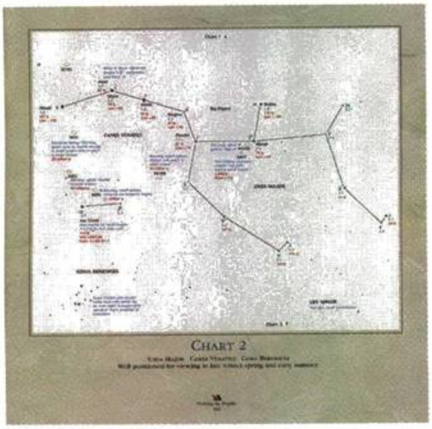

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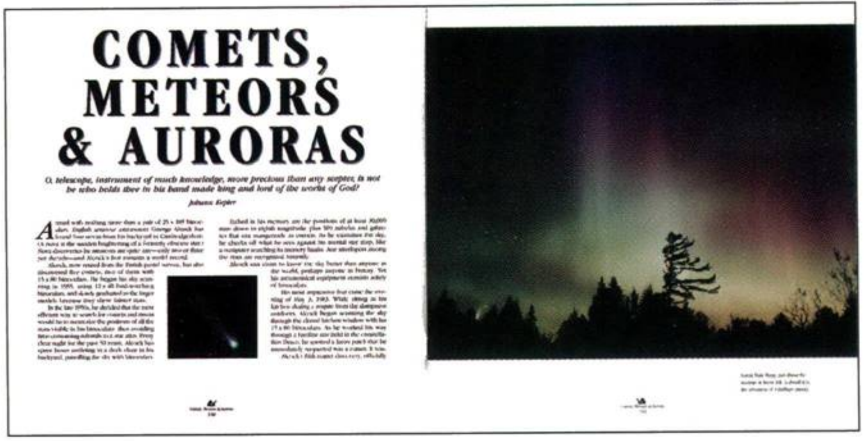

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Johannes Kepler

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That first view of Saturn. Fuzzy TV pictures of Neil Armstrong. Whatever it was, astronomers of all stripes recall the event that sparked their interest. *Karen Hopkin.*

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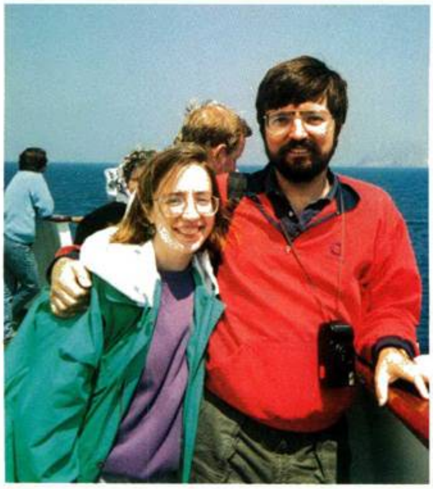

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Jerry Lodriguss

At *the* Eyepiece

Hooked on Astronomy

Remember the first time you looked through a telescope's eyepiece? It was likely your single most memorable as an astronomy hobbyist. Whether you looked at the moon or a distant, indistinct galaxy, the event probably struck you hard with the realization that to see things in the universe, all you had to do was to go outside with a telescope on a clear night and look in the right places. For me it was a view of Saturn through a 4¼-inch reflector. Having seen a little glowing ball of orangy light surrounded by sharply defined rings floating in a glistening field of a few stars, I was instantly hooked. I was 14 years old and my whole life changed.

Lick Observatory

Sandy Faber was hooked on astronomy in college.

Beginning on page 10, Washington-based science journalist Karen Hopkin explores this initial burst of curiosity about the universe we have all had. To write "Transforming Moments," she talked with a number of amateur and professional astronomers and ultimately focused on the lives of a dozen astronomers — some well-known and others not — who shared their moments of realization with the rest of us. We learn of Brian Marsden's experience as a five year old viewing a solar eclipse, which led him to want to calculate everything about how the universe works and eventually led to his position as gatekeeper of the world's astronomical discoveries. We learn how in college Sandy Faber became "an observatory groupie," getting paid $1 for every good shot of a planet or double star she made with the school's telescope. We learn how Elizabeth Aab, who recently was graduated from Trinity High School in Manhattan, savored her first view of the Whirlpool Galaxy as part of an educational program and how she now considers herself a stargazer.

The world's astronomy enthusiasts have diverse and amazing backgrounds. But whatever they be we have all shared magical moments. Looking up into a dark sky and realizing the immensity of the Milky Way Galaxy, and the cosmos beyond, is certainly humbling. Recalling the grandeur of the timescale of the universe and, as individuals, our very brief stint on planet Earth, adds to the feeling of awe. That the universe is so large and dynamic, so much beyond our normal sphere, bothers some greatly. It doesn't bother me at all. I like being a very small part of a very large universe and like especially being able to travel the cosmos at the eyepiece of a telescope, assisted by trusty maps and magazines. Indeed, it's something I've been hooked on for 22 years. I hope that you feel the same way.

Dave Eicher
Editor

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U.S. and International Newsstand Distribution
I.C.D., The Hearst Corp., New York, NY 10019

Canadian Newsstand Distribution
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Astronomy Home Page: http://www.astronomy.com

Explore the Universe 1999 (ISSN 1089–4926) is published annually by Kalmbach Publishing Co., 21027 Crossroads Circle, P.O. Box 1612, Waukesha, WI 53187–1612. *Astronomy* editorial phone: (414) 796-8776; advertising: (800) 558-1544; customer service: (800) 446-5489; subscriptions: (800) 533-6644, 7 days a week, 24 hours a day; fax: (414) 796-0126. SINGLE COPY PRICE: U.S. $5.95, Canada $6.95, and U.K. £2.95. Canadian price includes GST. BN 12271 3209 RT. Canadian and international orders payable in U.S. funds. POSTMASTER: Send address changes to: *Exploring the Universe 1999*, Kalmbach Publishing Co., 21027 Crossroads Circle, Waukesha, WI 53187–1612.

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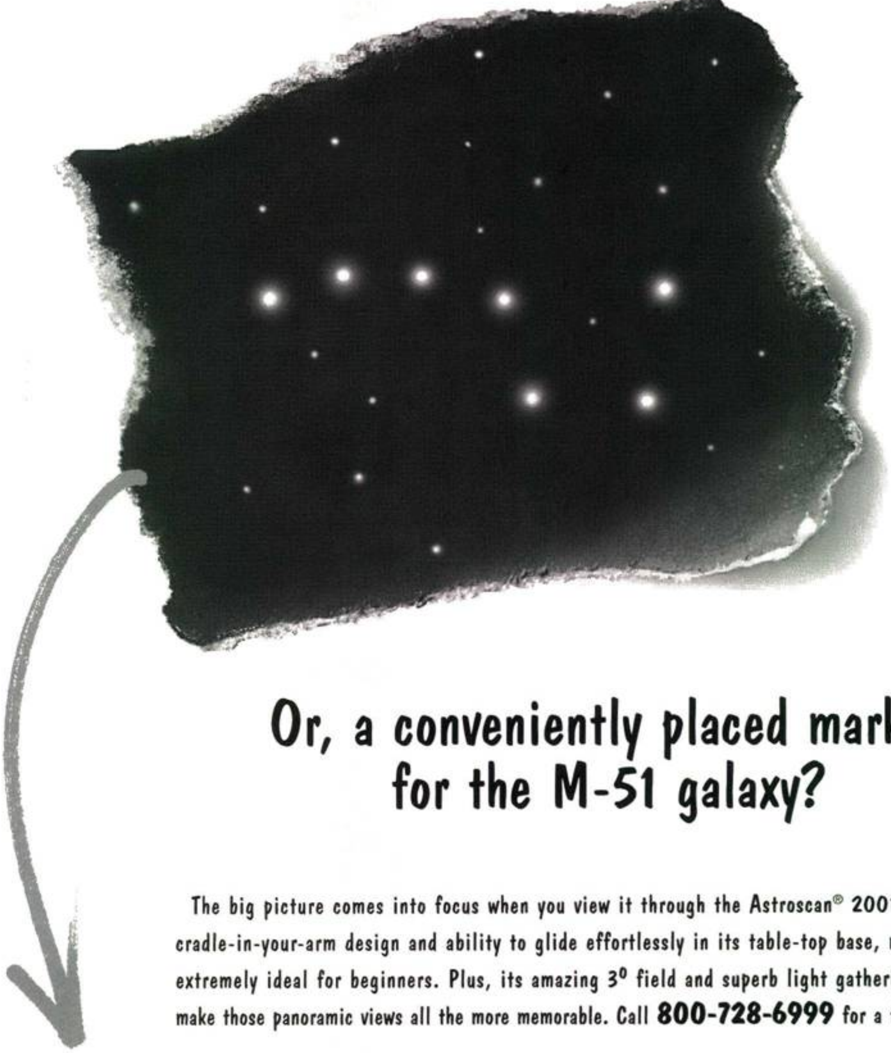

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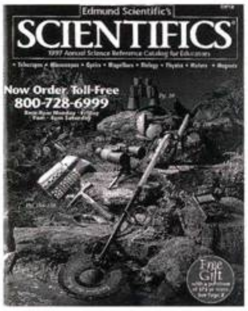

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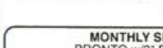

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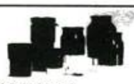

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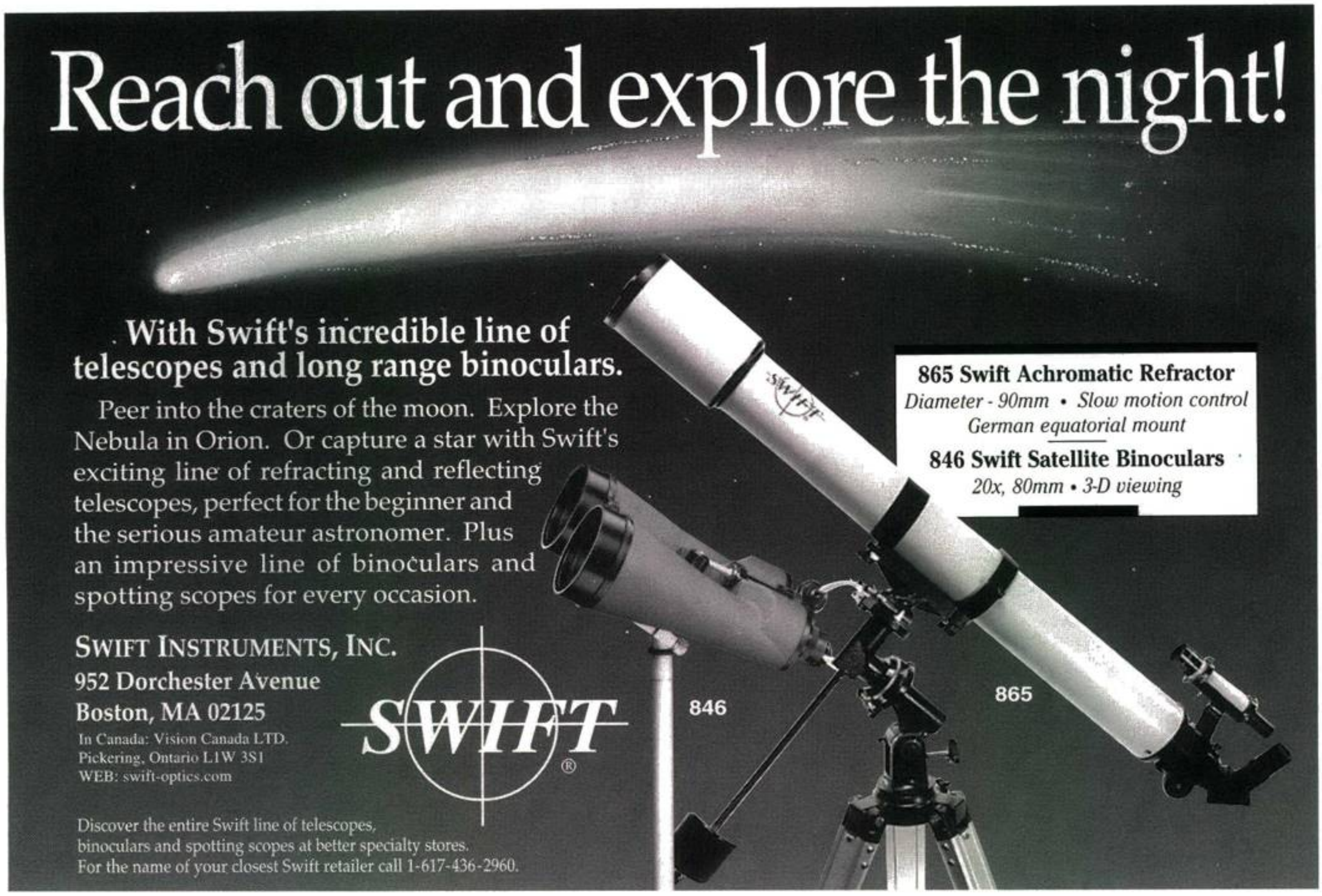
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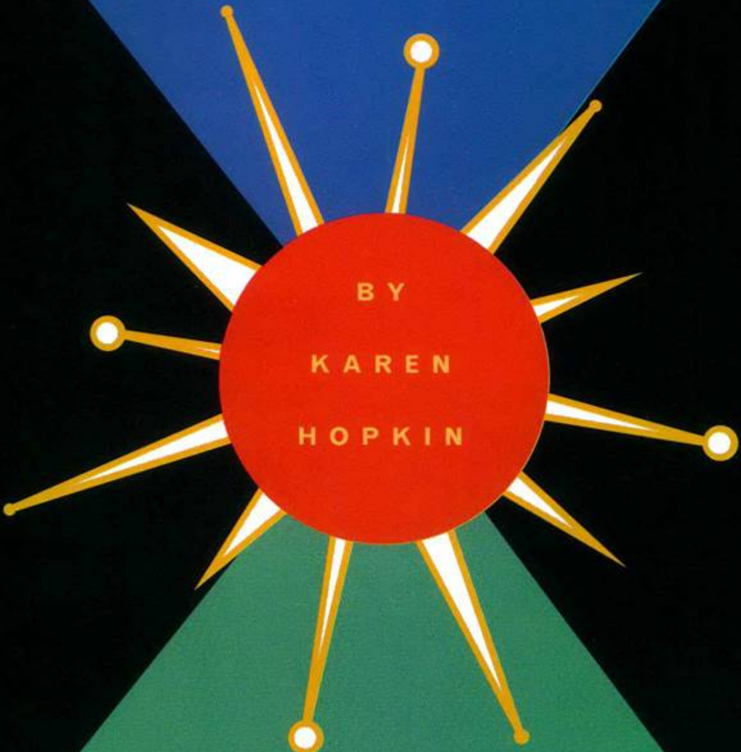
Astronomers recall pivotal experiences that set their lives on new courses.



BY KAREN HOPKIN

Like the stars they see, everybody's first experience with astronomy is unique. Remember the first time you gazed — curious and eager — into a dark night sky? For Jay White, the sensation of soaring through infinite space sparked his young imagination and inspired him to devote his professional life to astronomy and to communicate his enthusiasm to others. He now studies how pairs of stars, called binaries, exchange matter as the pairs closely circle their common centers of gravity.

Many of us find inspiration while watching the skies as children, while others find it during retirement. For some, the Southern Hemisphere fires the imagination. Some of us, like those who go on to careers in astronomy, marvel at an aurora waving like a green curtain beyond our bedroom windows. Some of us are excited by a solar or lunar eclipse, and for some an initiation into astronomy begins after rescuing a telescope from a neighborhood trash can.

What is important and most memorable is not how we started or even what we saw the first few times. It usually is how we feel that truly endures. Many mature astronomers — amateurs and professionals — have long forgotten the mosquito bites, the cold, wet dew in the grass, and other discomforts and distractions. They remember awakening their sense of awe and adventure. Indeed, your lifelong connection with the universe awaits discovery almost every night.

Amazed and Hooked

Dressed in her little astronaut suit as a child, Debra Meloy Elmegreen would fly a cardboard space capsule to distant worlds. Living in South Bend, Indiana, Elmegreen was spellbound by the stars that sparkled in the night sky. She got the telescope she wanted when she was in first grade. "I was amazed that stars were not five-pointed, like in cartoons," she says. "I was hooked."

Elmegreen also built her own telescopes — two 6-inch Newtonian reflectors and a cubical quad radio antenna. After she moved to Virginia at age 12, she hosted backyard star parties for her high-school friends. "We'd be up all night, counting meteors or listening to radio emissions from Jupiter," she recalls. "It would usually degenerate into music and dancing and stuff like that, but before that we would just look at the stars."

Now Elmegreen, an astronomer at Vassar College in Poughkeepsie, New York, studies the structure of galaxies to learn why stars form where they do and how galaxies interact with one another. She often is glued to her computer. But she still likes to observe, particularly in the winter, when the skies are most clear and the air is most crisp.

"I really do hate the cold," says Elmegreen, "but I never notice it when I'm out looking at the sky." Stargazing always reminds her why she became an astronomer. "I can go out and look at the Milky Way and it all really comes back home again."

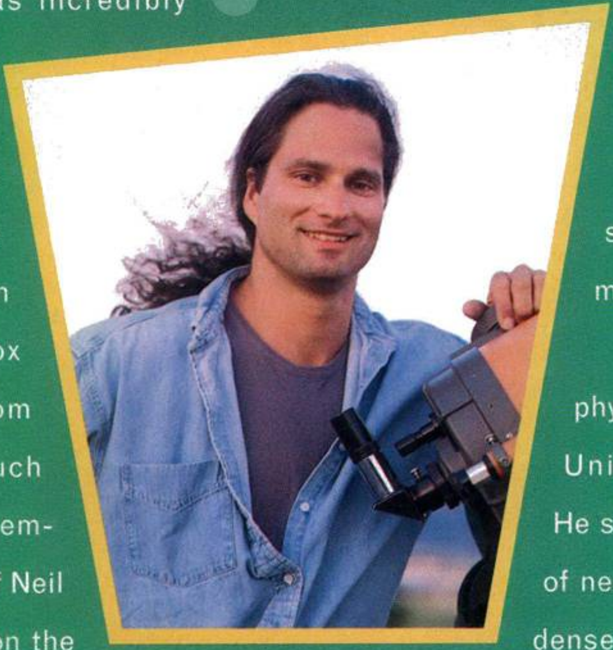
NO WAY, DUDE

"My God," is a one of the most common observations people make on first seeing Saturn's rings, says amateur astronomer Jim Whitehouse of Albion College in Michigan. Whitehouse and some fellow Michiganders would set up a 20-inch Dobsonian Obsession at the local YMCA camp, point the telescope toward Saturn, and then quietly bet whether each first-time viewer would say "Oh, wow" or "Oh, my God." One long-haired camp counselor surprised them all by peering into the eyepiece and saying, "No way, dude."

Whitehouse himself didn't get turned on to astronomy until he was in his 40s. He was hunting white-tailed deer in the Michigan woods when his buddy passed him the Bushnell binoculars he had been using to search for deer and told him to check out Halley's Comet, which was streaking through Pleiades at the time. "I found the comet," says Whitehouse, "but the thing that stunned me was the way Pleiades looked — like a handful of diamonds thrown across a piece of black velvet. It was just beautiful," he says. "Very spiritual."

LOST IN SPACE

Growing up in suburban Dallas, Bennett Link would lie on the driveway and look at the moon with his dad's binoculars. At age five, Link got his first peek at Saturn's rings while attending a star party. "I'd seen pictures of Saturn in a book," he says, "but then I looked through the telescope and I realized this was the real thing: It was incredibly exciting to me."



At age seven, Link wanted to be an astronaut. Sprawled on the living room floor in front of the Magnavox television, his mom asleep on the couch nearby, Link still remembers the fuzzy image of Neil Armstrong bounding on the moon. He was desperate to find out how the Apollo XI astronauts must have felt looking back at Earth. "Going to sleep, I would actually will myself to dream about traveling through space," he says.

The following summer, the Link family moved to Oklahoma, and young Bennett used the money he earned delivering the *Tulsa Tribune* to buy his first telescope, a Jason refractor. Through the crisp, chilly winters and hot sticky summers, Link would look for galaxies and nebulae — always trying to see farther, always trying to see more.

He remembers the first time he spotted the Andromeda Galaxy. It was a fuzzy little blob. "But it was packed with billions of stars whose light took two million years to get here," says Link. "It was just mind-boggling."

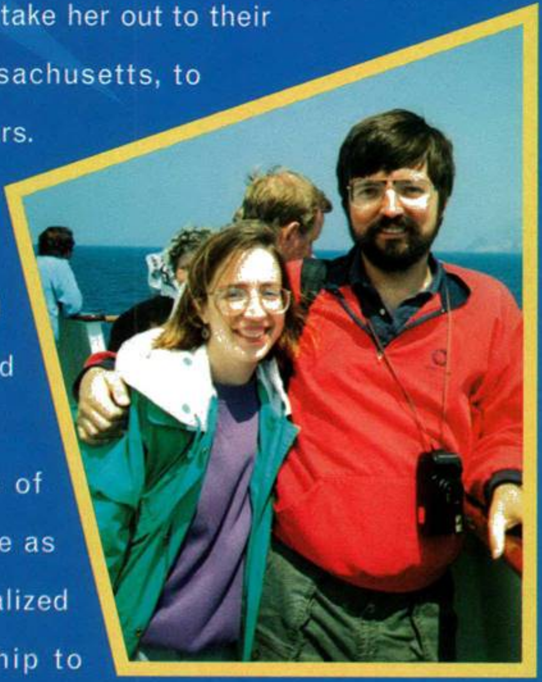
Today, Link is an astrophysicist at Montana State University in Bozeman. He studies the inner workings of neutron stars — the super-dense matter left behind after massive stars explode as supernovae. Although Link does most of his research in a university office seated in front of a computer screen these days, he still loves to lug a telescope into the field and scan the western sky. "You see things that stir something inside you," he says. "It happens every time I go out to observe."

SIBLING ALIGNMENT

Elizabeth Lada was five when her teenaged brother Charlie would take her out to their backyard in Webster, Massachusetts, to look at the moon and the stars. Charlie Lada bought his 4-inch Dynascope reflector with the money he earned playing trombone in a band with his father.

Growing up in the age of Sputnik, Charlie saw space as the next frontier. But he realized he didn't need a spaceship to explore the universe. "All you need is a telescope to get an astronomical tour," he says.

When Charlie went to Harvard to get his Ph.D. in astronomy, Elizabeth remembers relatives asking her if she wanted to become an astronomer just like her big brother. "And I would say, 'No way!'" she recalls. "I was in high school — I wanted to be independent." But her love of the night sky's beauty eventually swayed her. Now both siblings — Elizabeth at the University of Florida in Gainesville and Charlie at the Harvard-Smithsonian Center for Astrophysics in Cambridge, Massachusetts — study how stars and planets form. Says the Lada sister, "It's nice to have someone in the family who understands what I do."



THE VIEW FROM HOOSICK FALLS

Saturn's rings captured then-13-year-old Victor Pytko one cold pre-dawn morning after Christmas. Pytko lived in Hoosick Falls, a small town in upstate New York. He remembers throwing open his bedroom window and pointing his new Tasco refractor telescope at what appeared to be a bright double star in the dark blue sky. He saw Jupiter and Saturn in the same field of view. "My God, Saturn really did have rings," says Pytko.

Watching the skies gave young Pytko a sense of teenage purpose that had been missing. "Sneaking into bars, running with the cliques — it all seemed so frivolous when you could instead steal away into the quiet of night and see back into time a billion years," says the now-older amateur astronomer.

Bi-Coastal Cyberlinks

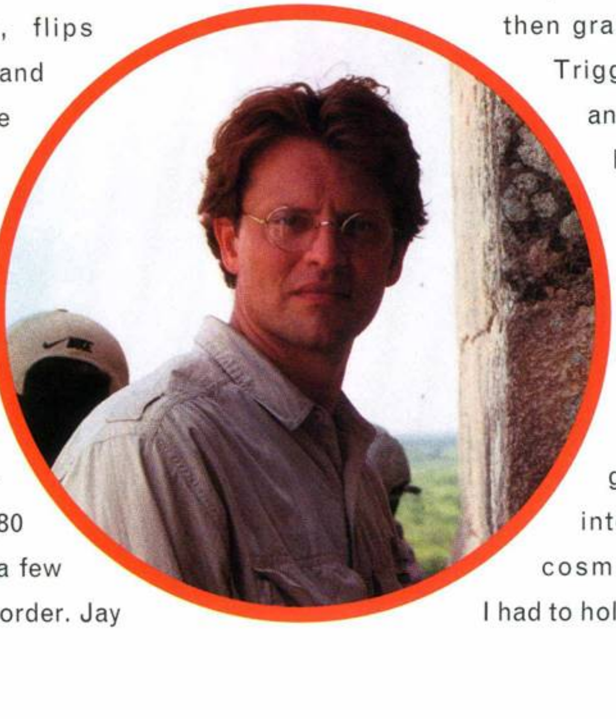
Some kids in New York link up with telescopes in their high school cafeterias. Thanks to the Telescopes in Education program, run by astronomers at the Jet Propulsion Laboratory, students can tap at computer keyboards in New York to point a 24-inch telescope at Mt. Wilson near Pasadena, California. Using specially designed software and talking on a speaker-phone with an operator in the dome, the students select their celestial targets with a point-and-a-click device and the images appear on their screens.

Elizabeth Aab, a recent graduate of Trinity High School on the Upper West Side of Manhattan, remembers the first time she saw the Whirlpool Galaxy via the program. "It was beautifully centered, perfectly exposed . . . It was like . . . Whoa. This is fantastic," she says.

Although Aab appreciates the cyber-astronomy program, she prefers the immediacy of going out and observing stars and galaxies the old-fashioned way. "Their photons are on the way to you while you're looking at them," she says. "It's as though you're having a dialog with the things you're seeing."

But the best part about touring the sky with a telescope, whether it's in the classroom or in a field, is knowing that everything's real, says Aab."It's like you're told a fairy tale, and then you find out it's true."

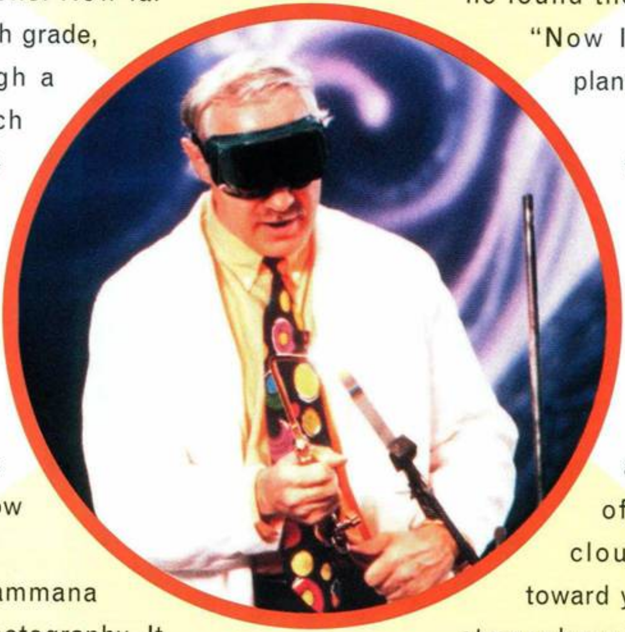
FIELD OF DREAMS



Late at night, Jay White wanders over to the campus observatory, flips switches to open the dome, and sits on the floor, watching the sky above Murfreesboro, Tennessee. It's dark and peaceful. The view transports the Middle Tennessee State University astronomer back to his childhood.

White grew up on a 100-acre farm about 50 miles (80 km) south of the university, a few miles north of the Alabama border. Jay would help his mother clear dinner dishes, then grab his binoculars, saddle up Trigger, his gray Shetland pony, and ride to the grassy fields with his German shepherd dog Nikki tagging along. After finding a dry spot in the field he'd lie on his back and scan the sky, Nikki sniffing nearby for gopher holes. "I would lie on the ground and imagine falling into space; falling through the cosmos," he says. "Sometimes, I had to hold onto the ground."

Eclipse Excitement



Dennis Mammana followed his dad behind the house for his dad's after-dinner cigarettes and pestered him with questions. How far away are the stars? In fourth grade, Mammana peered through a magnifying glass to search for the faintest star in the Milky Way in his *Weekly Reader*. "I wondered if I was the only human being who had ever taken the time to focus on this one star," he says. "Looking at places no one else had seen — I knew that's how I wanted to make my living."

Even as a teenager, Mammana was obsessed with astrophotography. It led him to his current position as resident astronomer at the Reuben H. Fleet space theater in San Diego, California. One day, the resident astronomer took an eclipse tour. "I used to think, 'So it gets dark in the daytime, what's the big deal?'" says Mammana. But he found the experience deeply moving. "Now I've got the rest of my life planned around solar eclipses."

After having half a dozen of them, Mammana still finds eclipse experiences difficult to describe. When the moon blocks out 95 percent of the sun's disk, Mammana says "things get very, very weird." The temperature drops, the air chills, and then the shadow of the moon — a huge black cloud off to the west — races toward you. At 98 percent totality, the atmosphere becomes otherworldly, even frightening. "I remember thinking, 'My God, something has gone horribly wrong,'" he says. "I couldn't believe how deeply it touched me."

SOUTHERN EXPOSURE

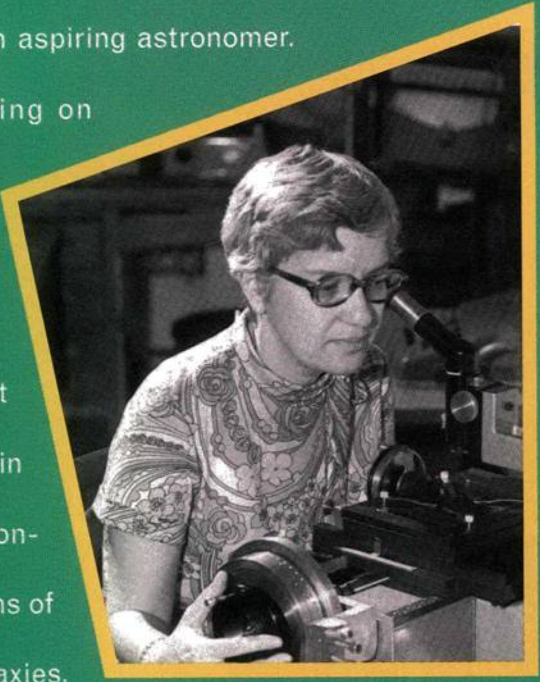
Sandy Faber didn't peer through a telescope until she she attended Swarthmore College, near Philadelphia, Pennsylvania. She loved it. "By senior year, I was an observatory groupie," says Faber, who was paid $1 for every good picture she took of a double star or planet using the school's 24-inch refractor telescope. Faber found the experience mystical as crickets chirped during the long exposures on summer nights. "When you can go out and just sit in a quiet place on a beautiful night, you feel you're in contact with the whole rest of the universe," she says.

Her first glimpse of the sky from the Southern Hemisphere was even more moving. Faber determines the age and size of distant galaxies as an astronomer at the University of California, Santa Cruz. Recently, she went to Chile to make observations with noted astronomer Alan Dressler. Faber stepped outside the observatory with her eyes closed, and when she opened them her whole world changed. "I realized that all of my life I had looked at the sky like a picture painted on a ceiling," she says. With the altered perspective, the walls of that imaginary room fell away and the sky became real: "It was as though I was standing on the edge of an asteroid, being swept toward the center of the galaxy."

HAND-ME-DOWN ASTRONOMY

When Vera Rubin was 10 she would lie in her bed and stare out the window at the stars, aurorae, and the slow movement of the planets. "I found watching the stars much more interesting than sleeping," she says. "I was captivated."

Watching the sky transformed the native of Washington, D.C., into an aspiring astronomer. "I couldn't imagine living on Earth and not trying to understand what was going on in the universe," she says. Now at the Carnegie Institution in her home town, Rubin continues to study how billions of stars move around in galaxies. And she still likes to gaze at the sky: "The view of the Milky Way on a dark night is the most beautiful view in the world."

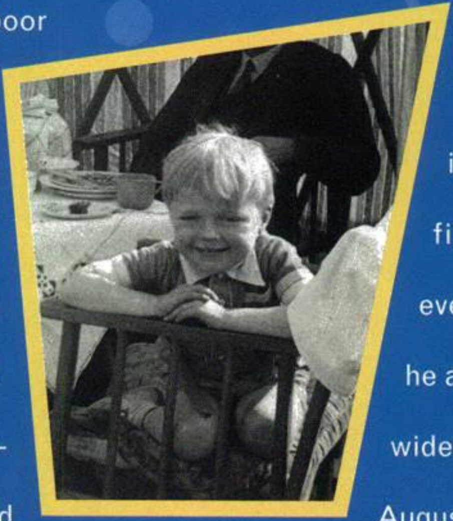


Rubin passed her love of astronomy and all its mysteries onto her daughter, Judith Young. Fresh out of sixth grade, Young remembers spending summer nights sitting on the back patio of her family's house, at the time in La Jolla, California, and gazing at the Milky Way until early morning. "I never wanted to go inside," Young says. At the time, she was leaning toward the pursuit of a career in chemistry; but only until her mother volunteered to teach an astronomy class at her high school. "The day she described black holes was the day I decided to be an astronomer," says Young.

Now at the University of Massachusetts in Amherst, Young studies star formation. When she isn't doing research or teaching classes, Young can be found watching the sun set from inside her sun wheel — a circle of stones that marks where the sun rises and sets throughout the year. Sitting alone in the field, with the summer breeze blowing and red-winged blackbirds and hawks flying overhead, Young enjoys spending time with the closest star — the sun.

MATHEMATICAL MASTER OF DISASTER

While most people find comets and asteroids visually fascinating, Brian Marsden is obsessed with the geometry and mechanics of their trajectories. "People observe because they want to be the first to see something new," says Marsden. "The same applies to people like me with poor eyesight who do calculations. I calculate something new, others see something new."



Marsden's first astronomical experiences were mathematical. He remembers the day — September 10, 1942: It was a warm and sunny afternoon — a rare treat in the south of England. He remembers coming home from school and seeing his mother sunning herself in the yard as she looked at a partial solar eclipse through a smoked glass. Marsden held up the dark glass and became excited, but not for the obvious reasons.

"I was anxious to know when the next eclipse would be, and how I could do the calculation — even at the age of five," he says. "I'm just weird that way."

Marsden wrote a letter to his grandfather, a teacher, who replied that the next eclipse visible from England would occur on July 9, 1945. Young Brian was inspired. He independently figured out that eclipses repeat every 54 years and one month, and he anticipated that there would be a widely visible eclipse in England on August 11, 1999. "I like working things like that out in my head," says Marsden, who now works at the Harvard-Smithsonian Center for Astrophysics in Cambridge, Massachusetts, where he calculates the orbits of comets and asteroids and predicts whether they'll strike anything — like Earth, for example. "It's not just science," he says. "It's great fun."

Karen Hopkin is a freelance writer based in Silver Spring, Maryland.

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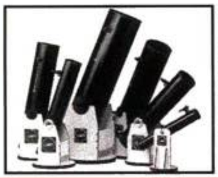

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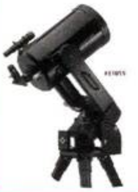

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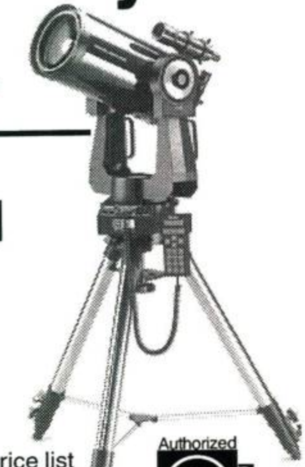

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A tour of the Cosmic Zoo

From the comfort of your backyard, you can see the universe's most amazing objects.

by Bob Berman

Our universe is loaded with amazing things. But where can you find them? How do exploded star fragments, say, and black holes, relate to the actual night sky? What do all those strangely colored stars tell us, and how can we get our hands on a galaxy? Let's see what's what by taking a quick cosmic inventory not of the textbook universe, but the actual, living, over-your-roof sky.

Fasten your seat belt. Our whirlwind night tour stops only at fascinating places, to see how exotic objects like colliding galaxies, evocative of science fiction, can be easy hands-on experiences.

It all starts by simply looking up and noticing a strange pattern that has been obvious, if misunderstood, since humans in furry underwear gazed up from their cave entrances. The stars aren't randomly sprinkled. Instead, they concentrate within a broad, creamy path that streams across the heavens and is especially obvious in the summer. Glance any distance away from this splendidly crowded boulevard and the sky appears relatively empty. This arrangement tells us that we live in a disk-shaped city of suns. Because we're embedded within this platter, our worm's-eye view shows millions of distant suns when we sight along the disk's thick dimension but few stars when we look "above" or "below" the plane.

Other galaxies, each containing billions or even a couple trillion suns and probably a similarly dizzying number of planets, are out there too, in a wonderful assortment of sizes and shapes. They can be found everywhere except along the Milky Way, since dust in our own galaxy's disk hides them from view.

The nearest major galaxy is also the brightest in the Northern Hemisphere: the Andromeda Galaxy, or M31. It's almost straight overhead at midnight on October nights, the tiny, fuzzy oval found at the distance from the tips of your outstretched thumb to index finger held at arm's length (about 15°) to the northeast of Alpheratz, at the northeastern corner of the Great Square of Pegasus. Slightly larger than our own Milky Way Galaxy, the Andromeda Galaxy is 2.2 million light-years away, meaning you're seeing light that embarked on its journey when our *Australopithecus* ancestors were being devoured by leopards on the African savanna.

A star similar to the sun ejected its outer layers, forming the beautiful Ring Nebula (M57) in Lyra.

Jack Newton

Sadly, the Andromeda Galaxy's glory is disguised by the unfortunate fact that it's tilted almost, but not quite, edgewise. Its 13° slant yields a shape that is sloppy rather than well defined. Through binoculars, M31's presence is obvious, its central radiance striking — but its spiral arms merely appear as a foggy, amorphous glow. Telescopes don't help much either. The smudge gets larger and brighter but not much better defined, although Andromeda's two brightest dwarf companion galaxies (the most common type of galaxy in the universe), M32 and NGC 205, become obvious.

The only other Northern Hemisphere galaxy that the naked eye can glimpse (and then only with difficulty under perfectly transparent conditions) is the small, face-on spiral galaxy M33, the Pinwheel Galaxy in Triangulum. It looks like a surprisingly large but shapeless smudge just an outstretched hand to the southeast from Andromeda. It stays blurry even through binoculars and telescopes. Still, bingo, you've suddenly bagged four galaxies under your belt in just a minute or two, and all in the same part of the autumn sky. These four galaxies, along with the Milky Way, belong to the Local Group — a relatively small galaxy cluster with at least 35 members.

LEFT: The Whirlpool Galaxy (M51) is a beautiful spiral galaxy near the handle of the Big Dipper. You can easily see the galaxy in binoculars, but you'll need at least a 10-inch scope to see the spiral arms. Jack Newton

ABOVE: The easiest galaxy to see is the one we live in: the Milky Way. Jerry Lodriguss

"Smudge" is also the best term to describe the telescopic appearance of most of the hundreds of visible members of the most famous cluster of galaxies, the Virgo Cluster. This galactic Happy Hunting Ground lies between the tail of Leo and the upper right arm of the "Y" of Virgo. Sweeping that region with any telescope uncovers dozens of little blurs. Prominent in the late evening southern skies of spring, this distant assemblage, lying an awesome 60 million light-years away (meaning we are seeing light that left shortly after the demise of the dinosaurs), does boast a few galaxies that offer detail in 8-inch or larger scopes. The best are outlying Virgo members: the Sombrero Galaxy (M104) and a beautiful edgewise city of suns called NGC 4565 in the adjoining constellation of Coma Berenices. The gargantuan elliptical galaxy M87, one of the largest galaxies known, provides another fascinating sight. This behemoth sits at the very heart of the Virgo Cluster.

If you feel a little let down by the fuzzy, shapeless telescopic appearance of galaxies, you're not alone. Gorgeous long-exposure astrophotos show spiral structure, and it's reasonable to want to see such features for yourself. When that urge overwhelms experienced observers, they head to one place alone — the wonderful face-on Whirlpool Galaxy (M51) — right near the handle of the Big Dipper. The Whirlpool can be seen year-round from mid-northern latitudes, but it can be best viewed in spring when it's high in the sky. But to see spiral arms in an object 23 million light-years away, you need bigger guns: A 10-inch telescope on a dark night is required to start seeing indications of spirality, and bigger is even better. Finding M51 is not too hard: Start with the star Alkaid, the star marking the tip of the Big Dipper's handle. M51 lies just 4° (or about the width of two fingers held together at arm's length) to the southwest.

The Whirlpool boasts a second distinction as well. It's the easiest-to-observe interacting pair of galaxies: The Whirlpool and its smaller companion galaxy exist in a perilous state of near-collision.

Pastel Colors

Fortunately, the heavens host a myriad of treasures that are far nearer — and so reveal much more detail — than external galaxies, and many of these look great in small telescopes or even binoculars. You might as well start with the stars.

Most normal suns are too faint and distant to be visible to the naked eye. The night sky instead features the oddballs, the stellar lighthouses, and, lacking only green, they present an Easter-egg assortment of pastel colors.

White stars look white because all parts of their rainbow-like spectra glow equally (mixing all colors produces white light). A blue star, like brilliant Rigel in Orion's foot, isn't just emitting that color; rather, it's simply radiating more blue light than any other hue, which means it's extremely hot. Since hot suns use their fuel quickly and die off in adolescence, all blue stars are young. Look how much instant info is yours from a quick color appraisal.

Red stars, on the other hand, are cool, making them so intrinsically dim that you wouldn't see them at all if they were normal sized. So spotting an orange or red star automatically means you've found a giant or supergiant, a star that has swelled in size 100 to 1,000 times the width of the sun. A bright example is Orion's famous shoulder star Betelgeuse (Alpha [α] Orionis), located about 430 light-years away. If Betelgeuse were substituted for the sun, it would fill the solar system out to the orbit of Jupiter.

By brightening all stars, binoculars and telescopes bring out many more colors than the naked eye alone can see. For a quick demonstration, point binoculars at the top two stars of the Great Square of Pegasus, dominating the southern sky on autumn nights. The rightmost, Scheat, is dramatically orange, the other, Alpheratz, is blue-white — tints only barely discernible to the naked eye.

There are yellow stars, too, like brilliant, giant, creamy Capella now rising into the northeast, or the more normal-sized (and therefore dim) 51 Pegasi halfway up the southern sky, just slightly to the right of an imaginary line connecting the rightmost two stars of the Great Square. That faint star shows strong evidence for having its own planet. Don't expect to see the planet, however; it's lost in the star's glare.

Dark Blotches

To gaze at the summer and autumn Milky Way is to see that there's more to our galaxy than just stars. Vast dark blotches interrupt the creamy glow, and though they looked like holes to early telescopic observers (the largest curtain of blackness nearly overhead these nights is called the Great Rift), we now know they're not empty. They're immense clouds of mostly hydrogen gas with a little bit of dust mixed in. Such nebulae look black when unilluminated, red when becoming energized by the energy of hot, newborn stars, and blue when reflecting light from nearby hot stars.

Not surprisingly, these various black, red, or blue gaseous areas are called dark, emission, and reflection nebulae respectively, and it would be nice if our eyes were more sensitive to low light levels so we could actually see their glorious colors. But they're not. Instead, most nebulae appear gray through binoculars or small telescopes and a bit greenish through larger ones. Sometimes a single region, like the famous Orion Nebula (M42) in the middle of the Hunter's "sword," rising in the east on autumn nights, boasts an amalgam of all three types (although it's primarily an emission nebula). This is where we see new stars being born. The Orion Nebula is 1,500 light-years away, meaning we're seeing light that was emitted at about the time the Vandals were sacking Rome.

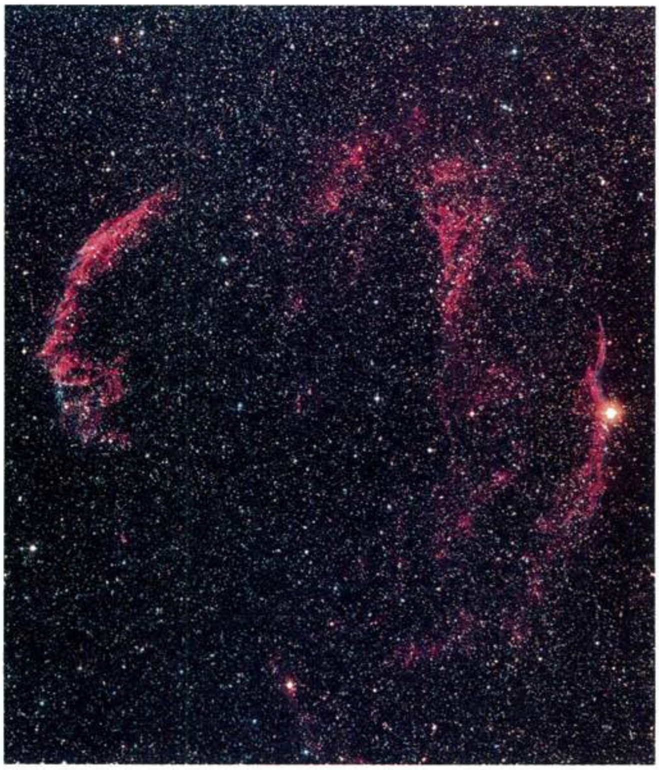
The brightest and most detailed nebulae have been backyard favorites for decades. One of the easiest-to-spot nebulae is the donut-shaped Ring Nebula (M57) near the bright star Vega in the west. That brilliant sun, made famous to the astronomically challenged in the book and movie *Contact*, is accompanied by a perfect parallelogram of little stars that serve as the Ring's eternal guide, as if in a Tolkienesque fable. The ghostlike donut lies halfway between the parallelogram pair farthest from Vega.

The Ring Nebula's small size and dimness place it marginally beyond the range of most binoculars, though your scope will make its ghostly appearance obvious enough. Its disk-like shape illustrates why 18th-century telescope users thought it looked like a planet, which is why they called the Ring and similar objects "planetary nebulae." But planetary nebulae are misnamed; they're actually expanding bubbles of gas blown off by dying stars that have masses similar to the sun's. Whereas dark, emission, and reflection nebulae represent the birthplaces of stars, planetary nebulae are the death throes of stars. When you look at a planetary nebula, you're getting a sneak preview of the sun's fate some six billion years from now.

For extra excitement, the dramatic theme of star death echoes throughout the sky, assuming many strange and wondrous forms. Besides forming planetary nebulae, stars like the sun collapse into white dwarfs when they run out of nuclear fuel. These mini-stars pack the mass of a star into a sphere the size of Earth, giving them a density so high that a mere teaspoon of white dwarf stuff would weigh as much as a truck. The closest white dwarf to Earth is the little companion to the famous Dog Star Sirius. Unfortunately, it's too close to its brilliant primary to be seen this year.

With a small telescope, you can see the white dwarf Omicron^2 Eridani, in the meandering constellation of Eridanus the River, in the southern sky during January evenings. To find Omicron^2, start with brilliant Rigel, which marks Orion's right foot, and move a fully extended thumb-tip-to-index-fingertip (about 15°) to the right (west). Omicron^2 is the bottom star of the first up-down star pair that you'll come to. Actually, this bottom star is part of a triple star system (more on that later), and Omicron^2 is the second brightest of the trio.

While stars similar to the sun die a relatively peaceful death, stars with about 10 or more times the mass of the sun blow themselves to kingdom come — as supernovae. The tattered remains of the exploded star is a supernova remnant. The Veil Nebula (NGC 6960, NGC 6992-5) in Cygnus is an easily observed supernova remnant. Through a telescope, look high up in the autumn night sky 3° south of Epsilon (ε) Cygni, the brightest star in the eastern wing of the Swan. The Veil's chaotic filaments tumble willy-nilly around the faint naked-eye star 52 Cygni. Seeing a supernova's aftermath is the closest any of us want to get to one of these titanic blasts.



ABOVE: The Veil Nebula (NGC 6960 and 6992-5) in Cygnus is the tattered remains of an exploded star. Bill and Sally Fletcher

RIGHT: The Pleiades (M45) is the archetypal open cluster — a grouping of newborn stars. Jason Ware

Groupings of Suns

Among the prettiest objects in the galaxy are groupings of suns. About half of all stars are members of binary systems, in which two stars are gravitationally locked in orbit around each other. Many others are members of triple, quadruple, quintuple, or even sextuple systems, leaving solitary suns like our own in the distinct minority. It's always fun to view double or multiple stars, especially when they're bright and easily separated under low power. When the components also offer color contrasts, they create works of art. Take a telescopic peek at the famous blue and gold stars of Albireo, marking the head of Cygnus the Swan; any size telescope will do. While there are dozens of tinted binaries, Albireo is probably the finest in all the heavens. For an alternative, try Gamma (γ) Andromedae, high overhead in the autumn — the third one along the string that starts with the Great Square and leads toward Perseus.

Sometimes you'll encounter hundreds of stars crammed together in a small part of the sky, like the Pleiades (M45), about 380 light-years away in Taurus. The stars of these open clusters were born together inside the same gas cloud. Halfway up the eastern sky in the autumn, and conspicuous with the naked eye, the Pleiades offers a vivid demonstration of how low power is sometimes the best power.

Observers quickly learn that the Pleiades and other open clusters look more impressive with simple binoculars than through most telescopes. A binocular's wide field and seven to 10 power are ideal for such spread-out objects. In fact, some clusters are so "open" — like the scattered stars of the Hyades cluster, which are loosely thrown around the bright star Aldebaran — that even binoculars offer too high a power. In these cases, the naked eye alone gives the best view. Discover your own clusters, they're that numerous. Some groupings don't even have popular names: Point binoculars at Orion's belt and see how it's encircled by dozens of lovely star points, like fireflies.

While loose star groupings like open clusters are big and beautiful, globular clusters deliver the most intense visceral impact. Here, up to a million suns pack themselves into a tight spherical ball that, through a 6-inch or larger telescope, is beyond description. From mid-northern latitudes, the most striking globular is the Hercules Cluster (M13), halfway up the western sky on autumn evenings. Look between Zeta (ζ) and Eta (η) Herculis, two of the stars in that constellation's "keystone." A tiny, perfectly circular blob through any pair of binoculars, M13 is amazing in medium and large telescopes; many consider it the very finest sight in the skies above North America and Europe. Hercules lies on a line between two of the sky's most brilliant stars, Arcturus and Vega. M13 is about 23,000 light-years away, meaning we're seeing light that was emitted when our human ancestors in Europe were struggling to survive the Ice Age.

Globulars are old clusters. With their gas and dust depleted, no new star formation is occurring. What you see is what you're going to get. Unlike the dynamic starbirth and nebular regions, globulars are staid and stable places.

LEFT: To see stars of different colors, look no farther than the constellation Orion. Cool Betelgeuse (upper left) appears red, while searing hot Rigel (lower right) appears blue. Alan Dyer

ABOVE: Globular cluster M13 in Hercules is one of the most spectacular telescopic sights in the heavens. More than 100,000 stars are packed together in a small volume of space. Kim Zussman

The Abyss

The last stop on our cosmic tour transports us from the beautiful to the ultra-strange: invisible but spellbinding black holes. These collapsed stars do not emit light, so you won't see them no matter how big your telescope is. But you can at least see where black holes are located. Black holes harbor a fierce gravity that twirls any companion star around like an angry toddler mistreating a stuffed panda. High overhead in Cygnus the Swan in late evening, ½° (one moon diameter) east of the star Eta (η) Cygni (the only medium-bright star in the swan's neck), lies a binocular star forgettably named HDE 226868. Something is making this distant massive sun wildly whirl around a vacant spot every six days, while a blizzard of x rays gusts from that emptiness. The x rays flicker rapidly, a sure sign that they are coming from a tiny source. All these clues point firmly toward identifying that "empty spot" as a black hole. The x rays presumably arise from gas spiraling down the ultimate cosmic drain into the abyss of the black hole.

Our tour of the night, which started with the upbeat radiance of the Milky Way, finishes with dark, brooding mystery. And that's entirely appropriate: The yawning distances and the colossal number of unknowns are well symbolized by the complexities and contradictions of the sky itself. We will never grow bored, for the future promises endless discoveries. But meanwhile we have an ocean in which to cast our lines, whose known treasures can keep us entertained, enthralled, and enraptured every clear night of our lives.

Bob Berman's book Secrets of the Night Sky *(HarperCollins) is available in paperback. His new book* Cosmic Odyssey: A Renegade Astronomer's Guide to Our World and Beyond *will be published by William Morrow in November 1998.*

The Scoop

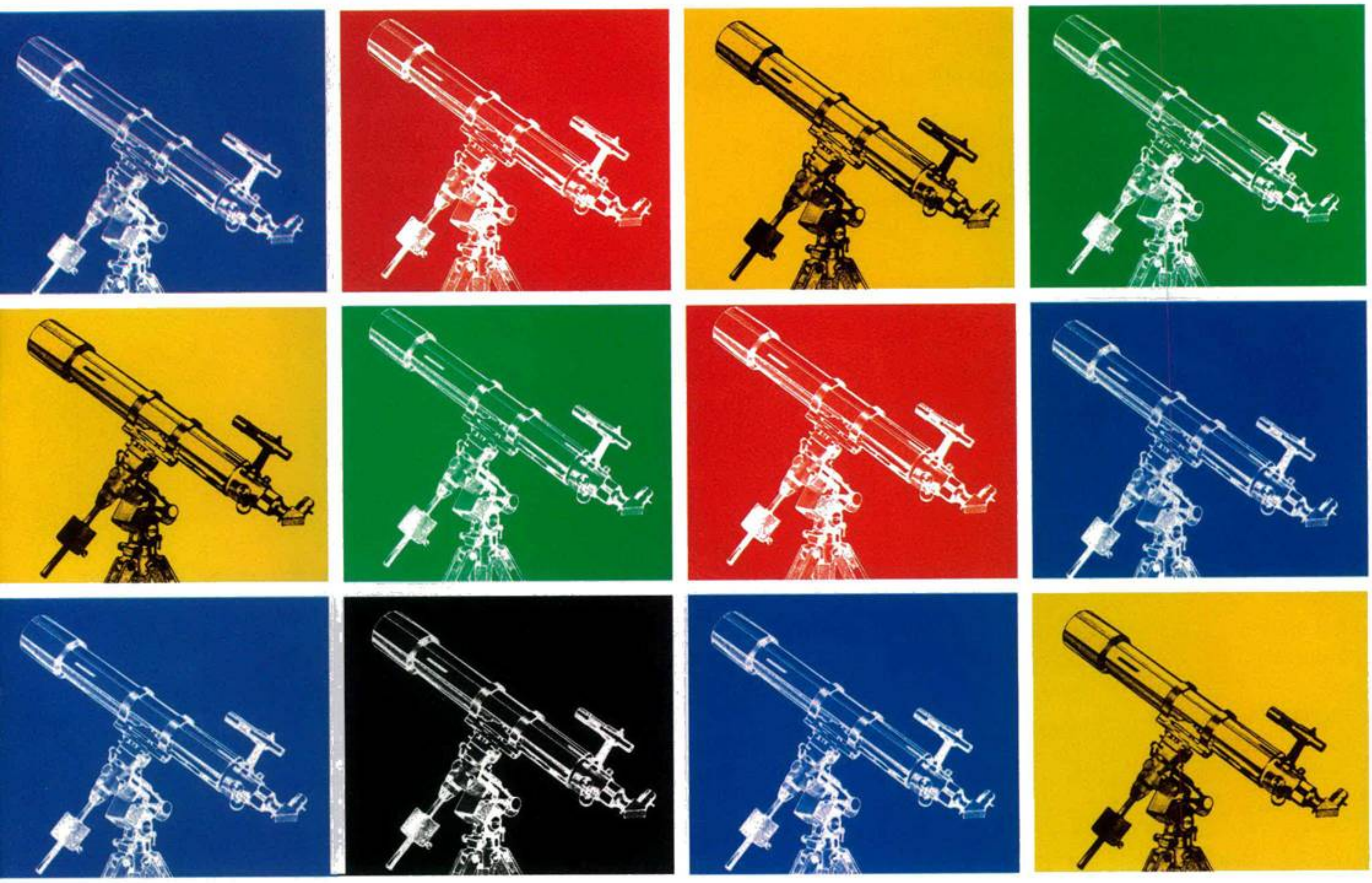
Whether a beginner looking for that first telescope or a night savvy amateur in search of a newer model, we've got the guide to help you locate the instrument you seek.

by Phil Harrington

PERHAPS THE MOST IMPORTANT decision an amateur astronomer makes is what telescope best suits his or her needs. Which telescope is right for you? It's a highly personal question that can quickly become an overwhelming task when faced with advertising claims in stacks of catalogs. We offer some advice that we hope will aid you in your decision.

Today's astronomers use one of three basic telescope designs: the refractor, the reflector, and a hybrid called the catadioptric. The most recognizable of the three is the **refractor**. It is characterized by a long, thin tube and uses a series of lenses to bring an image to focus. A large lens, the objective, is found at the front end of the tube. The observer looks through a small, eyepiece lens at the back.

The second telescope type, **reflector**, uses a large primary mirror at the bottom of the tube to gather light from a target and reflect it to a focus. Though the primary mirror may look flat, it's actually concave or curved inward like a shallow bowl. Many different reflector designs have



on Scopes

been devised over the years. The most popular type today was invented by Sir Isaac Newton in 1681 and is aptly named the Newtonian reflector. A Newtonian reflects light from the primary mirror to a small, flat secondary mirror or diagonal tilted at 45° near the top of the tube. The light bounces off of the secondary mirror through a hole in the tube's side and into a waiting eyepiece.

The third type of telescope is a hybrid called the **catadioptric**. These telescopes combine aspects of a refractor and a reflector. Light passes through a large front lens (the corrector plate) toward a primary mirror at the back of the tube. The light reflects from the primary mirror to a convex-shaped secondary mirror in the center of the corrector plate. The secondary returns the light to the back of the tube and through a small hole in the primary. From here the light goes out the back of the telescope to a waiting eyepiece. The most common type of catadioptric instrument on the market today is the Schmidt-Cassegrain Telescope (SCT).

The Language

Refractors, reflectors, and catadioptric instruments share many common functions and jargon. A telescope's size is always referred to by its **aperture** — the diameter (usually expressed in inches, centimeters, or millimeters) of the instrument's main mirror or lens. A 3-inch refractor has an objective lens 3 inches (80mm) across, while the primary mirror in a 4-inch reflector measures 4 inches (100mm) in diameter. Another important aspect is a telescope's length. This is determined

	Aperture	Focal ratio	Tube material[1]	Tube length	Mounting type[2]	Clock drive	Slow motion	Setting circles	Finder	Eyepiece	Total weight
Achromatic Refractors											
Price Range: Under $300											
Celestron Firstscope 80 AZ	3.1	11.4	Aluminum	n/s	Alt-az	no	yes	no	6x30	25mm SMA	18
Orion ShortTube 80	3.1	5	Aluminum	15	n/s	no	no	no	6x30	25mm K, 10mm K	n/s
Price Range: $300 to $600											
Celestron C80-HD	3.1	11	Aluminum	n/s	GEM	opt	yes	yes	6x30	20mm P	29
Celestron C102-AZ	4	9.8	Aluminum	n/s	Alt-az	no	yes	no	6x30	20mm P	28
Celestron Firstscope 80 EQ WA	3.1	5	Aluminum	n/s	GEM	no	yes	yes	no	25mm SMA	13
Celestron Firstscope 80 EQ	3.1	11.4	Aluminum	n/s	GEM	no	yes	yes	6x30	25mm SMA	24
Meade 390	3.5	11	Aluminum	39	Alt-az	no	yes	no	6x30	25mm MA	17
Orion Observer 80 EQ Ultra	3.1	11.3	Aluminum	n/s	GEM	no	yes	yes	6x30	25mm K, 9mm K	n/s
Orion/Vixen VX80	3.1	11.4	Aluminum	n/s	Alt-az	no	yes	no	6x30	25mm P	n/s
Price Range: $600 to $1,000											
Celestron C102-HD	4	9.8	Aluminum	n/s	GEM	opt	yes	yes	6x30	20mm K	36
Meade 102ACHR/500	4	9	Aluminum	32	GEM	opt	yes	yes	6x30	25mm P	n/s
Meade 395	3.5	11	Aluminum	39	GEM	opt	yes	yes	6x30	25mm MA	27
Orion SkyView 90	3.5	11.1	Aluminum	n/s	GEM	opt	yes	yes	6x30	25mm K, 9mm K	25
Tele Vue Ranger	2.8	6.8	Aluminum	18	n/s	no	no	no	no	20mm P	3.5*
Price Range: $1,000 to $1,500											
Orion/Vixen VX90 GP	3.5	11.1	Aluminum	n/s	GEM	opt	yes	yes	6x30	26mm P	42
Orion/Vixen VX102 GP	4	9.8	Aluminum	n/s	GEM	opt	yes	yes	6x30	26mm P	48
Tele Vue Pronto	2.8	6.8	Aluminum	18	n/s	no	no	no	no	20mm P	6*
Price Range: $1,500 to $2,000											
Meade 102APO/500	4	9	Aluminum	32	GEM	opt	yes	yes	8x50	26mm SP	n/s
Orion/Vixen VX90 GP Fluorite	3.5	9	Aluminum	n/s	GEM	opt	yes	yes	6x30	26mm P	41
Newtonian Reflectors (Altitude-Azimuth Mounts)											
Price Range: Under $300											
Celestron Star Hopper 4.5	4.5	8	Aluminum	n/s	Alt-az	no	no	no	5x24	25mm SMA	18
North Star 6	6	8	Cardboard	48	Dob	no	no	no	no	25mm	35
Stargazer Steve Kit	4.25	10.5	Cardboard	~45	Dob	no	no	no	1x	10mm K	16
Stargazer Steve SGR-3	3	10	Cardboard	31	Alt-az	no	no	no	1x	18mm K	7
Price Range: $300 to $500											
Celestron Star Hopper 6	6	8	Cardboard	n/s	Dob	no	no	no	no	25mm SMA	40
Coulter Odyssey 8	8	4.5 or 7	Cardboard	36 or 56	Dob	no	no	no	opt	27mm	39-45
Edmund Astroscan	4.25	4	Plastic	17	Ball	no	no	no	no	28mm RKE	13
Meade Starfinder 6	6	8	Cardboard	48	Dob	no	no	no	5x24	25mm MA	34
Meade Starfinder 8	8	6	Cardboard	48	Dob	no	no	no	5x24	25mm MA	44
North Star 8	8	6	Cardboard	48	Dob	no	no	no	no	25mm	43
Orion Deep-Space Explorer 6	6	8	Cardboard	50	Dob	no	no	no	5x24	25mm K	33
Orion Deep-Space Explorer 8	8	6	Cardboard	51	Dob	no	no	no	5x24	25mm K	41
Price Range: $500 to $1,000											
Celestron Star Hopper 8	8	6	Cardboard	n/s	Dob	no	no	no	no	25mm SMA	62
Coulter Odyssey 10	10.1	4.5 or 5.6	Cardboard	45 or 56	Dob	no	no	no	opt	27mm	69
Coulter Odyssey 13	13.1	4.5	Cardboard	57	Dob	no	no	no	opt	27mm	97
Meade Starfinder 10	10	4.5	Cardboard	45	Dob	no	no	no	5x24	25mm MA	62
Meade Starfinder 12.5	12.5	4.8	Cardboard	58	Dob	no	no	no	5x24	25mm MA	96
MorningStar MS-8	8	6 or 8	Cardboard	50	Dob	no	no	no	1x	yes (one)	45
North Star 10	10	6	Cardboard	60	Dob	no	no	no	no	25mm	54
Orion Deep-Space Explorer 10	10	4.5	Cardboard	50	Dob	no	no	no	5x24	25mm K	68
Orion Premium DS Explorer 10	10	5.6	Cardboard	61	Dob	no	no	no	no	26mm P	77

by its **focal length** — the distance from the objective lens or primary mirror to its focus. Focal length is also commonly expressed in either inches, centimeters, or millimeters. One last piece of lingo is familiar to photographers, it's the telescope's **focal ratio.** This can be calculated by dividing an instrument's focal length by its aperture.

For instance, a 6-inch telescope with a focal length of 48 inches has a focal ratio, or f/number, of f/8; while an 8-inch telescope with a focal length of 40 inches has a focal ratio of f/5.

Calculating a telescope's **magnification** is also simple, but you need to know both the telescope and eyepiece focal lengths. To determine magnification, divide the telescope's focal length by that of the eyepiece — be sure all the units of measure are the same. A 6-inch f/8 telescope has a focal length of 48 inches (8 x 6 = 48) or 1,200 millimeters. That means a 25mm eyepiece yields a magnification of 48x, while the 12mm eyepiece produces 100x.

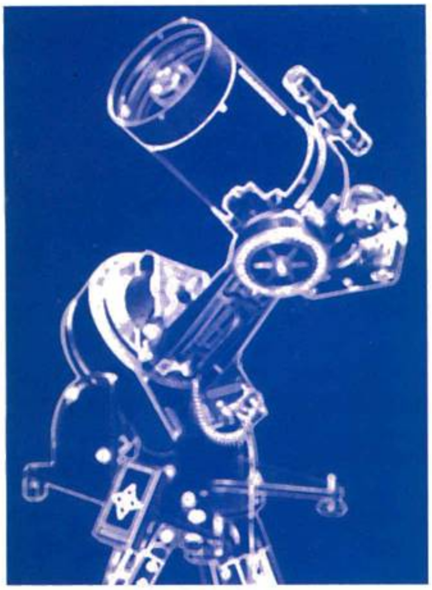
Many people believe that a telescope's power or magnification is its single most important feature, but that is far from the truth. You do need to magnify the image to see detail, but too much magnification can work against you. The problem, a telescope can only gather so much light based on its aperture. As magnification rises, the object's light is spread over an increasingly larger area. This dims the image and makes focusing more difficult. Beyond a certain magnification, the image becomes an unfocusable blob.

How much magnification is enough? The often-cited rule is not to exceed 60x per inch of aperture, though this will vary depending on the quality of the telescope's optics as well as the observing conditions.

Consumer Considerations

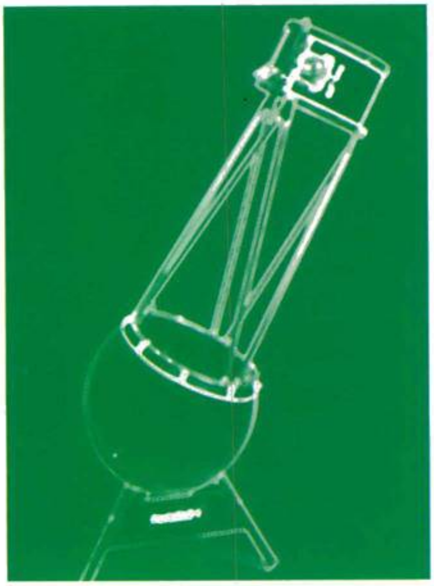
Optical quality should always be a top priority when choosing a telescope. The performance of a mirror or lens is based on its optical curve(s), which must be extremely precise. The accuracy of a mirror or lens is expressed in fractions of a wavelength of light. You may read about a mirror that is accurate to one-eighth of a wave. That may sound impressive, but what does it actually mean?

Take a look at the visible spectrum, from red to violet. Each color has a different wavelength — usually expressed in nanometers (nm) or Angstroms (Å).



Amateur telescopes are designed to transmit wavelengths of light to which the human eye is most sensitive. That wavelength is 550nm (0.00055mm or 0.00002 inches) in the middle of the visible spectrum, the yellow-green portion. For a lens or a mirror to be accurate to one-eighth wave, its surface shape cannot deviate by more than one-eighth of this wavelength (0.000069 mm or 0.000003 inch).

Most companies do not quote precise numbers when specifying their instruments' optical quality. Instead, they say that their telescope optics are "diffraction limited." This means the optics are so good that performance is limited only by the wave properties of light itself, and not by any flaws in the lens or mirror's accuracy.



In terms of importance, the telescope's mount ranks with the quality of its optics. A good mount must be strong enough to support the telescope's weight while minimizing vibrations. Without a sturdy mount to support the telescope, even the finest instrument will produce blurry, wobbly images. The mounting must also provide smooth motions when moving the telescope from one object to the next, allowing easy access to any part of the sky.

Telescope mounts may be separated into two categories — altitude-azimuth and equatorial. **Altitude-azimuth** mounts move horizontally (left to right) along the azimuth axis and vertically (up and down) along the altitude axis. Better azimuth mounts are outfitted with "slow-motion" controls, one for each axis. By twisting one or both of the slow-motion control knobs, the observer can fine tune the telescope's aim. Unfortunately, many azimuth mounts are too small and lightweight to carry their telescopes steadily.

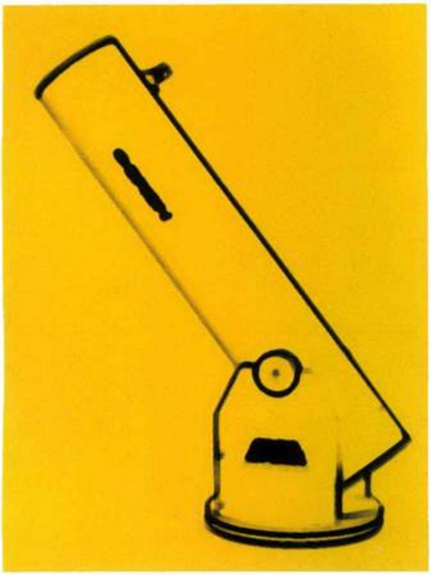
In the past 25 years, a variation of the altitude-azimuth mount called the

	Aperture	Focal ratio	Tube material[1]	Tube length	Mounting type[2]	Clock drive	Slow motion	Setting circles	Finder	Eyepiece	Total weight
StarMaster Oak Classic	7	5.6	Composite	43	Dob	no	no	no	opt	no	41
Starsplitter Compact 8	8	6	Two-pole	48	Dob	no	no	no	opt	no	35
Price Range: $1,000 to $1,500											
Celestron Star Hopper 11	11	4.5	Cardboard	n/s	Dob	no	no	no	no	25mm SMA	95
Mag One PortaBall 8	8	6	Alum truss	n/s	Ball	no	no	no	1x	no	30
Meade Starfinder 16	16	4.5	Cardboard	66	Dob	no	no	no	5x24	25mm MA	170
Orion Premium DS Explorer 12.5	12.5	4.8	Cardboard	65	Dob	no	no	no	no	26mm P	98
Orion Premium DS Explorer 16	16	4.5	Cardboard	76	Dob	no	no	no	no	26mm P	175
Starsplitter Compact 10	10	6	Two-pole	60	Dob	no	no	no	opt	no	40
Takahashi MT-130	5.2	6	Aluminum		n/s	no	no	no			n/s
Price Range: $1,500 to $2,000											
Celestron Star Hopper 14	14	4.5	Cardboard	n/s	Dob	no	no	no	no	25mm SMA	135
Celestron Star Hopper 17.5	17.5	4.1	Cardboard	n/s	Dob	no	no	no	no	25mm SMA	225
MorningStar MS-10	10	8	Alum truss	n/s	Dob	no	no	no	1x	yes (one)	75
StarMaster Large Aperture 10	10	6	Alum truss	60	Dob	no	no	no	1x	no	74
Starsplitter Compact 12.5	12.5	4.8	Two-pole	60	Dob	no	no	no	opt	no	55
Starsplitter Compact II 10	10	6	Alum truss	60	Dob	no	no	no	opt	no	35
Starsplitter Compact II 12.5	12.5	4.8 or 6	Alum truss	60/72	Dob	no	no	no	opt	no	40
Newtonian Reflectors (Equatorial Mounts)											
Price Range: Under $300											
Celestron Firstscope 114 Deluxe	4.5	8	Aluminum	n/s	GEM	n/a	yes	yes	5x24	25mm MA	19
Celestron Firstscope 114 Premium	4.5	8	Aluminum	n/s	GEM	n/a	yes	yes	6x30	25mm MA, 10mm MA	19
Edmund 3	3	6	Plastic	15	Fork	no	no	no	1x	15mm RKE	12
Orion ShortTube 4.5 EQ	4.5	8.8	Aluminum	18	GEM	no	yes	yes	5x24	25mm K, 10mm K	n/s
Price Range: $300 to $500											
Orion Optics Europa 114 (UK)	4.5	8	Aluminum	32	GEM	opt	yes	yes	6x30	25mm, 9mm	27
Orion Telescopes ShortTube	4.5	8.8	Aluminum	17	GEM	opt	yes	yes	6x30	25mm K, 9mm K	n/s
Orion Telescopes SkyView 4.5	4.5	8	Aluminum	n/s	GEM	opt	yes	yes	6x30	25mm K, 9mm K	27
Orion Telescopes SpaceProbe 4.5 EQ	4.5	8	Aluminum	n/s	GEM	no	yes	yes	5x24	25mm K	n/s
Starsplitter Gem 4.5	4.5	8	Aluminum	n/s	GEM	opt	yes	yes	6x30	25mm P, 10mm P	40
Price Range: $500 to $1,000											
Celestron C114-HD	4.5	8	Aluminum	n/s	GEM	opt	yes	yes	6x30	20mm P	28
Meade 114NT/500	4.5	8	Aluminum	n/s	GEM	opt	yes	yes	6x30	25mm MA	n/s
Meade 127NT/500	5	8	Aluminum	n/s	GEM	opt	yes	yes	6x30	25mm MA	n/s
Meade 4500	4.5	8	Aluminum	33	GEM	opt	yes	yes	6x30	25mm MA	27
Meade Starfinder Equatorial 6	6	8	Cardboard	48	GEM	opt	yes	yes	6x30	25mm MA	57
Meade Starfinder Equatorial 8	8	6	Cardboard	48	GEM	opt	yes	yes	6x30	25mm MA	69
Meade Starfinder Equatorial 10	10	4.5	Cardboard	45	GEM	opt	yes	yes	6x30	25mm MA	97
Orion Optics Europa 150 (UK)	6	5	Aluminum	28	GEM	opt	yes	yes	6x30	25mm, 9mm	33
Orion Optics Europa 200 (UK)	8	6	Aluminum	45	GEM	opt	yes	yes	6x30	25mm, 9mm	47
Orion Optics SX150 (UK)	6	6	Aluminum	33	GEM	opt	yes	yes	6x30	25mm K, 9mm K	40
Starsplitter Gem 6	6	5	Aluminum	n/s	GEM	opt	yes	yes	6x30	25mm P, 10mm P	40
Starsplitter Gem 6 Premium	6	5	Aluminum	n/s	GEM	opt	yes	yes	6x30	25mm P, 10mm P	40
Price Range: $1,000 to $1,500											
Orion Optics Europa 250 (UK)	10	4.8	Aluminum	43	GEM	opt	yes	yes	6x30	25mm, 9mm	57
Orion Optics SX200 (UK)	8	6	Aluminum	45	GEM	opt	yes	yes	6x30	25mm	48
Orion Optics SX250 (UK)	10	4.5	Aluminum	43	GEM	opt	yes	yes	6x30	25mm	55
Orion Optics GX150 (UK)	6	6	Aluminum	33	GEM	yes	yes	yes	6x30	n/s	44
Price Range: $1,500 to $2,000											
Orion/Vixen R200SS	7.9	4	Aluminum	27	GEM	opt	yes	yes	6x30	26mm P	43
Orion Optics GX200 (UK)	8	6	Aluminum	45	GEM	yes	yes	yes	6x30	n/s	53

Dobsonian has become extremely popular for supporting Newtonian reflectors with a 6-inch or larger aperture. The telescope tube moves up and down in altitude on a pair of round altitude bearings that ride on cut-outs in an open-ended wooden box, the rocker box. The rocker box is placed on the ground and pivots left and right in azimuth like a Lazy Susan. Dobsonian mounts are often made of wood or wood by-products, which dampens vibrations far better than metal. Though they may look simplistic, Dobsonian mounts are wonderfully stable.

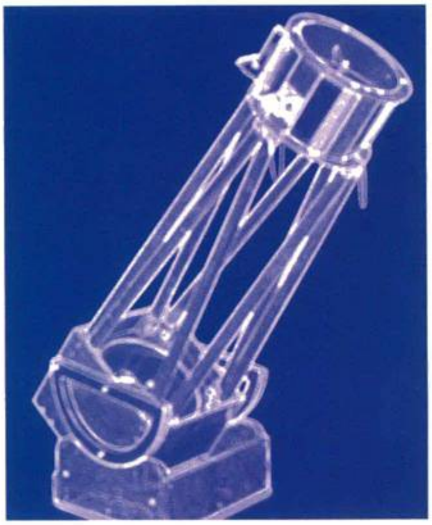
Traditional alt-azimuth mounts and Dobsonian mounts share some drawbacks. Unless you are observing at the poles, celestial objects appear to trace long arcs across the sky. With an alt-azimuth mount, the telescope must be nudged both horizontally and vertically in a step-like fashion to keep up with the sky's motions. This is much less convenient than the single motion enjoyed by an equatorial mount.

Like the alt-azimuth mounts, **equatorial** mounts have two perpendicular axes. They are referred to as the right ascension axis and declination axis.



There are many benefits to using an equatorial mount, the greatest is the ability to attach a motor drive to the right ascension axis so the telescope will follow the sky. The down side of equatorial mounts: They are almost always larger, heavier, more expensive, and more cumbersome than alt-azimuth mounts.

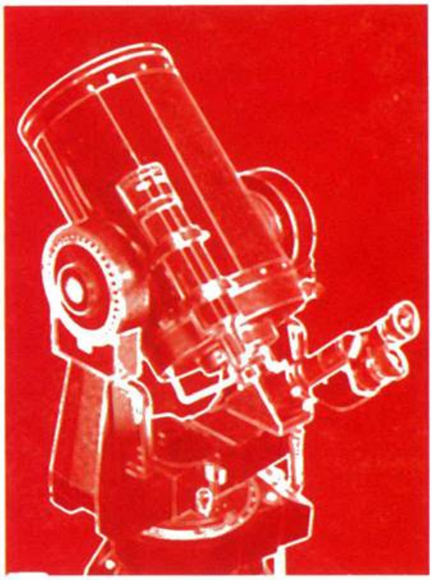
There are several different equatorial-mount designs, but the two most popular among amateur astronomers are the German equatorial mount and the Fork mount. The German equatorial mount is shaped like a tilted letter "T," with the polar axis represented by the long leg and the declination axis marking the T's crossbar. The telescope is mounted to one end of the cross bar, while a weight is secured to the other for counterbalance. If properly designed, German equatorial mounts are very sturdy, but at the same time, they can be very heavy. One designed to hold an 8-inch reflector might weigh between 50 and 100 pounds, while a Dobsonian mount weighs 20 pounds or less.



Fork equatorial mounts, usually supplied with more compact telescopes like catadioptrics, support their telescopes on bearings set between two short "prongs" which move the telescope in declination. The tines commonly extend from a rotatable circular base which serves as the right ascension axis. The biggest pluses with fork mounts are light weight and compact design. The minuses stem from fork prongs that are too lightweight or compact. If this is the case, the prongs will transmit even the smallest vibration to the telescope. This in turn will cause the image to dance about in the eyepiece. Most of today's fork-mounted telescopes offer a balance in design specifications and steadiness.

Another thing to consider when buying a telescope is what accessories come with the instrument. Eyepieces and finderscopes are especially critical. A **finderscope** is a small, low-power refractor telescope mounted on the telescope tube to help the observer aim the instrument. Finderscopes are specified in the same manner as binoculars. A 6x30 finder, for example, has an aperture of 30mm and yields a magnification of 6x. Most experienced observers agree that the smallest useful size for a finderscope is 8x50. Under typical suburban skies, an 8x50 finder will see objects to about 8th magnitude, roughly the limit of many popular star atlases. Smaller finders will show fewer stars, making it more difficult for the observer to find his or her way around the sky.

A popular alternative to the traditional finder is a "one-power aiming device" that allows you to point to the general area of the sky where the object you seek is located. These devices let the observer aim the telescope by looking through a clear window that has a red bull's-eye or dot superimposed on it. Simply align the dot or bull's-eye with your target and you're there. Several of these finders are being marketed today, though the original Telrad remains the most popular.



If this is your first telescope, then **eyepieces** are an especially important consideration. As mentioned earlier,

	Aperture	Focal ratio	Tube material[1]	Tube length	Mounting type[2]	Clock drive	Slow motion	Setting circles	Finder	Eyepiece	Total weight
Schmidt-Cassegrain Catadioptrics											
Price Range: Under $1,000											
Celestron C5 Spotting Scope	5	10	Aluminum	11	n/s	no	no	no	6x30	25mm SMA	6*
Price Range: $1,000 to $1,500											
Celestron C5+	5	10	Aluminum	11	Fork	yes	yes	yes	6x30	25mm SMA	23
Celestron Celestar 8	8	10	Aluminum	n/s	Fork	yes	yes	yes	6x30	25mm SMA	37
Celestron G8	8	10	Aluminum	n/s	GEM	opt	yes	yes	6x30	25mm HM, 8mm H	45
Meade 203SC/500	8	10	Aluminum	n/s	GEM	opt	yes	yes	6x30	25mm MA	n/s
Meade LX10	8	10	Aluminum	23	Fork	yes	yes	yes	6x30	25mm MA	49
Meade LX50	8	10	Aluminum	25	Fork	yes	yes	yes	6x30	25mm MA	71
Orion XSN200 (UK) Schmidt-Newt	8	4	Aluminum	27	GEM	opt	yes	yes	6x30	25mm	46
Price Range: $1,500 to $2,000											
Celestron Celestar 8 Deluxe	8	10	Aluminum	n/s	Fork	yes	yes	yes	6x30	26m P	40
Celestron Celestar 8 Computerized	8	10	Aluminum	n/s	Fork	yes	yes	yes	6x30	25mm SMA	37
Celestron Celestar 8 Computerized Deluxe	8	10	Aluminum	n/s	Fork	yes	yes	yes	6x30	26mm P	40
Meade LX50	10	10	Aluminum	31	Fork	yes	yes	yes	8x50	25mm MA	89
Orion/Vixen VC200L	7.9	9	Aluminum	n/s	GEM	opt	yes	yes	6x30	26mm P	46
Maksutov-Cassegrain Catadioptrics											
Price Range: Under $1,000											
Intes MK 67	6	10	Aluminum	n/s	n/s	no	no	no	7x35	no	n/s
Meade ETX Astro	3.5	13.8	Aluminum	15	Fork	yes	yes	yes	8x21	26mm SP	9
Meade ETX Spotting Scope	3.5	13.8	Aluminum	15	n/s	no	no	no	8x21	26mm SP	9*
Orion Argonaut 150	6	12	Aluminum	n/s	n/s	no	no	no	7x35	no	10*
Price Range: $1,000 to $1,500											
Intes MK 66	6	12	Aluminum	n/s	n/s	no	no	no	7x50	no	n/s
Intes MK 69	6	6	Aluminum	44	n/s	no	no	no	7x40	no	n/s
Intes MN 61 (Mak-Newtonian)	6	6	Aluminum	44	n/s	no	no	no	7x50	no	n/s
Intes Micro Alter 603	6	10	Aluminum	n/s	n/s	no	no	no	12x55	30mm K	n/s
Price Range: $1,500 to $2,000											
Ceravolo HD145 (Mak-Newtonian)	5.7	4.5 or 6	Aluminum	25/36	n/s	no	no	no	no	no	12*
Intes Micro Alter 703	7	10	Aluminum	n/s	n/s	no	no	no	12x55	30mm K	n/s
Meade LX50	7	15	Aluminum	33	Fork	yes	yes	yes	6x30	25mm MA	82

Notes

1. Tube material:

Aluminum: Solid-wall aluminum tube

Alum truss: Open truss built from 6 or 8 aluminum poles

Cardboard: Sonotube or similar concrete-form tubing commonly used in construction

Composite: Cardboard-like tube coated with a vinyl finish

Plastic: Solid-wall plastic tube

Two-pole: Open design that uses two poles to support eyepiece mount and diagonal mirror assembly

2. Mounting type:

Dob: Dobsonian-style altitude-azimuth mount

Fork: Fork equatorial mount

GEM: German equatorial mount

n/s: Not supplied; telescope mount must be purchased separately

3. Depending on the type and design of mounting, slow-motion controls, clock drives, and setting circles may or may not be available. Dobsonian mounts, for instance, do not come outfitted with any of these, although a clock drive and digital setting circles can be retrofitted by industrious amateurs.

4. "Total weight" includes both telescope and mounting, while "heaviest assembly" lists the weight of the heaviest single part that a user is likely to carry out into the field. If the weights are the same in both columns, then the telescope and mounting are usually transported together. In addition, the following abbreviations apply:

n/s: Not supplied by manufacturer

*: Not applicable, usually denoting a telescope that is sold without a mounting; instead, a mounting much be purchased separately, which, depending on the mount used, may cause the total instrument weight to vary. In these cases, the weight quoted is that of the optical tube assembly. Bear in mind that the mounting will probably be heavier.

All weights are as supplied by the manufacturer and have not been independently verified. All are expressed in pounds (rounded to the nearest pound), except for binoculars, which are expressed in ounces. To convert, there are 16 ounces per pound and 2.2 pounds per kilogram.

eyepieces are rated by focal length, not magnification. In general, you will want two or three eyepieces for viewing. One should produce low power, another for moderate magnification, and a third for high-powered views. Select the appropriate focal lengths based on the aperture of your telescope, remembering the rules of over-magnification cited earlier. A good mix might be a 22-mm to 30-mm eyepiece for low power, 12mm to 17mm for moderate power, and 7mm to 10mm for high power.

While an eyepiece must be selected based on a telescope's aperture, the eyepiece barrel must be the proper size to fit into the telescope's focusing mount. Most use 1.25-inch diameter eyepieces, a standard that has been around for years. Many departmentstore telescopes only accept subdiameter, 0.965-inch eyepieces which are frequently of poor quality, causing telescope performance to lower dramatically. Large-aperture amateur telescopes often come with giant focusing mounts that can accept both 1.25-inch eyepieces as well as huge 2-inch-diameter eyepieces.

Also be aware of the eyepiece's optical design. Many telescopes come with Kellner eyepieces, or variations called "Modified Achromats" (abbreviated MA or SMA). These are fine to begin with, but better designs are out there. (To learn more about today's eyepiece market see "Getting to the Focal Point," *Astronomy*, June 1998.)

One of the best ways to select a good telescope is to seek out the help of a local amateur astronomy club. Chances are at least one member already owns the telescope you are considering, and he or she will be happy to share personal experiences, both good and bad. Plan on attending a club observing session, where members set up their telescopes side by side to share with each other the excitement of sky watching. Most will be happy to share the eyepiece, giving you the opportunity to compare views before you buy. To find out if there is a club near you, contact local planetariums, museums, and nature centers. A directory of astronomy clubs is also available from the Astronomical Society of the Pacific on the Internet, at http://aspsky.org/html/resources/amateur.html.

Once you've decided what you want, be sure to shop at the right stores. Most toy and department stores do not sell telescopes with high-quality optics. Camera stores may sell a few top-notch telescopes, but often these high-end instruments are intermingled with an overabundance of poor imitations. This can make it difficult to tell the good instruments from the bad. Ask the salesperson for advice, but remember that he or she is trying to sell you something, so take their counsel cautiously. The telescopes listed in the accompanying table are generally far better than those sold in mass-market outlets.

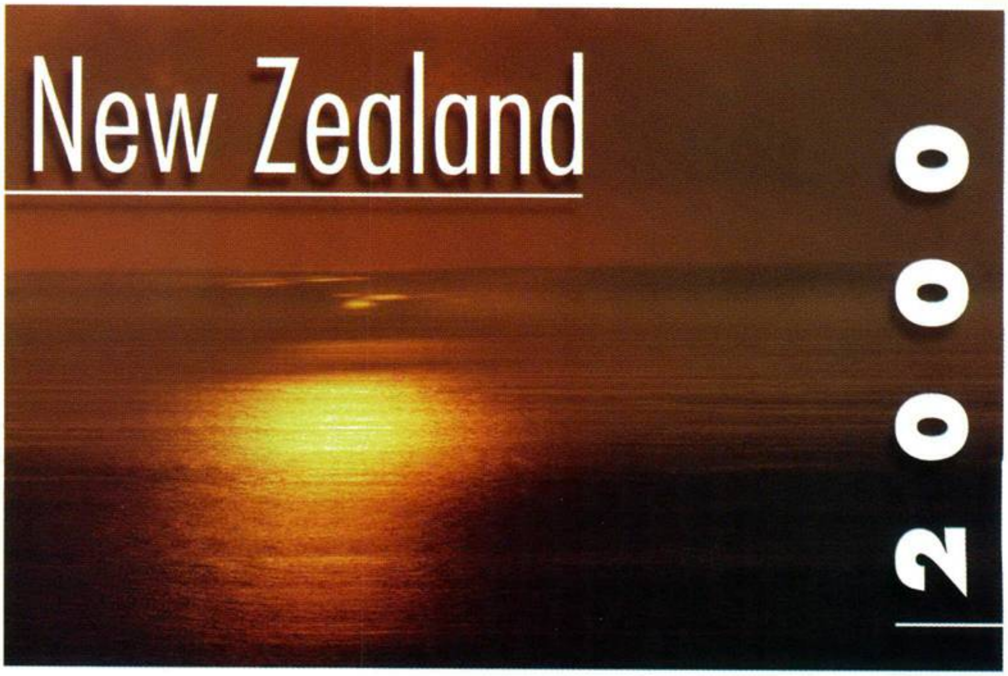
Some telescopes are sold through networks of dealers, while others are only sold directly from the company to the consumer. If you plan on purchasing an instrument from a dealer, make your decision on more than price alone. Ideally, it's easiest to purchase from a local outlet, but if one is unavailable, then mail order may be your only alternative. In that case, make certain to ask about "hidden costs," such as exorbitant shipping and handling charges.

Remember to take care when choosing a telescope. If selected and cared for properly, a telescope will last a lifetime. You and your new partner will spend many enjoyable hours traveling through the universe. ■

Phil Harrington is the author of five books for the amateur astronomer, including Star Ware: The Amateur Astronomer's Ultimate Guide to Choosing, Buying, and Using Telescopes and Accessories. *Visit his home page at http://ourworld.compuserve.com/homepages/pharrington/.*

Astronomy Magazine presents

The Millennium Tour



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Astronomy's

1999 Guide to the Sky

JAN

Glimpse an Asteroid with Your Naked Eye

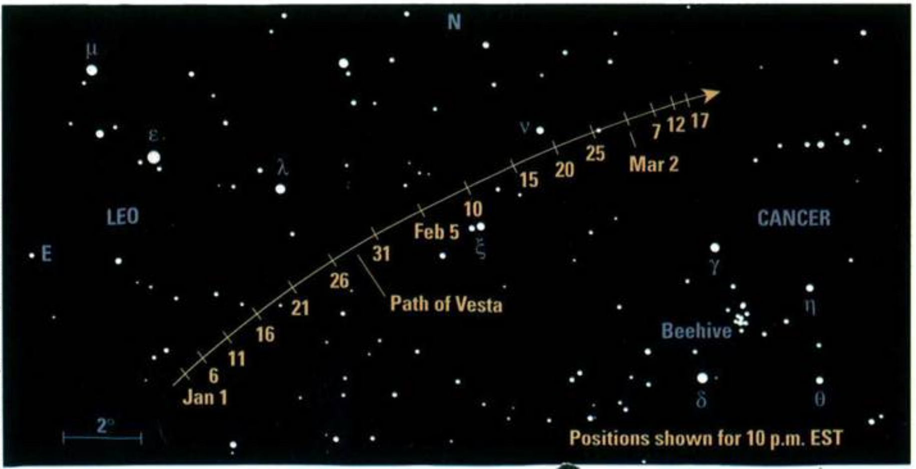
This year sees a big upswing in the number of spacecraft exploring the solar system – a level of excitement not seen since the early Voyager days. This month the Mars Surveyor 98 Lander is due to be launched toward the Red Planet, the second major Mars mission in as many months (last month should have seen Mars Climate Orbiter sent on its way), and another spacecraft arrives to study a near-Earth asteroid.

Lying between Mars and Jupiter is a zone little explored — that of the asteroids. Some asteroids cross the orbit of Mars and venture into near-Earth space. The first of these to be identified was Eros in 1898, which can come within 14 million miles of our blue planet. This month Eros sees a visitor from Earth as the Near-Earth Asteroid Rendezvous mission reaches its target. On January 9, in a major first, the NEAR spacecraft will attempt to go into orbit around the 9- by 9- by 25-mile-wide asteroid. Over the next few months its orbit will be slowly reduced to an altitude of 200 miles and eventually to just 22 miles, providing the first comprehensive scientific survey of a near-Earth asteroid.

One of the best known and brightest of the main-belt asteroids, Vesta, comes to opposition in early February. Discovered in 1807, it was the fourth asteroid to be discovered. Since then tens of thousands have been found, but Vesta remains one of the most popular for observers because it ranks as the brightest. Opposition occurs on February 4, when the asteroid lies in Cancer. On that date it passes 2° east of the 5.1-magnitude star Xi (ξ) Cancri. It then glows at magnitude 6.2, so it is possible to detect it with the naked eye if conditions are perfect. It's certainly an easy target in binoculars. Watch over a few nights, making a note of the arrangement of stars in the field of view each night, and Vesta will betray itself by its motion in the same way it did on its discovery night. By late February the full moon interferes with observation, but March finds Vesta moving to the north of the fine open star cluster, the Beehive (M44). Take this chance to join in the fun and explore a neglected region of the solar system.

ASTEROIDS IN 1999

Name	Opposition date	Magnitude	Constellation
4 Vesta	February 4	6.2	Cancer
40 Harmonia	February 14	9.8	Leo
11 Parthenope	February 15	10.0	Leo
10 Hygiea	February 15	9.7	Leo
8 Flora	March 28	9.6	Virgo
9 Metis	April 18	9.6	Virgo
3 Juno	May 25	10.2	Serpens Caput
6 Hebe	December 9	8.3	Orion
532 Herculina	December 10	9.7	Orion
29 Amphitrite	December 11	8.8	Auriga



Positions shown for 10 p.m. EST

All Illustrations by *Astronomy*: Elisabeth Rowan

Exploring the Winter Sky

Have you ever become lost in an unfamiliar city or state? Chances are you used two things to get around – a map and some signposts. In much the same way, these two items can help you find your way around the sky in any season. Fortunately, in addition to our seasonal sky charts, there are two major signposts provided for us in the sky. Each seasonal description will talk about the first one – the Big Dipper: a group of seven bright stars in the constellation Ursa Major.

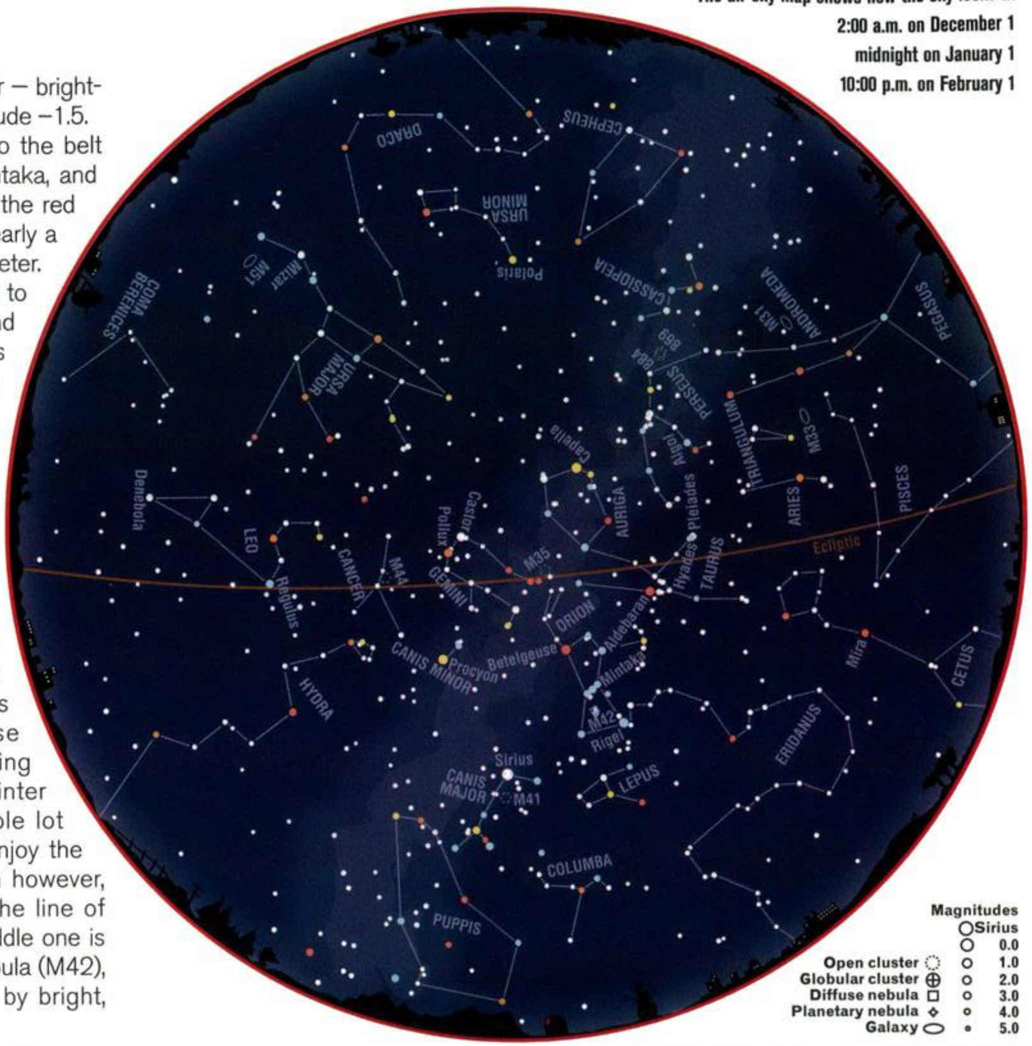
Winter sees the Big Dipper in the northeastern sky, with its triple-starred handle pointing toward the horizon and the four-starred bowl standing highest. The entire sky rotates around a point near Polaris, a 2nd-magnitude star found by extending a line from the uppermost pair of stars in the bowl across the sky to the left of the Dipper.

Turn around with your back to the Dipper and you'll be facing the diamond-studded winter sky. The second great signpost in the sky, Orion the Hunter, is central to the brilliant scene. Three closely spaced 2nd-magnitude stars in a straight line form the unmistakable belt of Orion. Extending the imaginary line joining these stars to the upper right leads to Taurus the Bull and its orangish 1st-magnitude star, Aldebaran. Reverse the direction of your gaze to the belt's lower left and you cannot miss Sirius the Dog Star – brightest in all the heavens at magnitude –1.5.

Now move perpendicular to the belt from its westernmost star, Mintaka, and find at the upper left of Orion the red supergiant star, Betelgeuse, nearly a thousand times the sun's diameter. Continuing this line brings you to a bright pair of stars, Castor and Pollux. Two lines of fainter stars extend from this pair back toward Orion – these represent Gemini the Twins. At the northeastern corner of this constellation lies the beautiful open star cluster M35.

Above Orion and nearly overhead on winter evenings is brilliant Capella in Auriga. Extending a line through the shoulders of Orion to the east leads you to Procyon in Canis Minor. Once you have these principal stars mastered, using our chart to discover the fainter constellations will be a whole lot easier. Take your time, and enjoy the journey. Before leaving Orion however, aim a pair of binoculars at the line of stars below the belt – the middle one is actually the glorious Orion Nebula (M42), a stellar nursery illuminated by bright, newly formed stars.

The all-sky map shows how the sky looks at
2:00 a.m. on December 1
midnight on January 1
10:00 p.m. on February 1


DRACO
CEPHEUS
URSA MINOR
Polaris
CASSIOPEIA
ANDROMEDA
M31
PEGASUS
COMA BERENICES
M51
Mizar
URSA MAJOR
869
884
PERSEUS
Algol
TRIANGULUM
M33
ARIES
PISCES
Capella
AURIGA
Pleiades
Hyades
TAURUS
Ecliptic
Denebola
LEO
Regulus
CANCER
M44
Castor
Pollux
GEMINI
M35
ORION
Aldebaran
Betelgeuse
Procyon
CANIS MINOR
Mintaka
M42
Rigel
Mira
CETUS
ERIDANUS
HYDRA
Sirius
CANIS MAJOR
M41
LEPUS
COLUMBA
PUPPIS
Magnitudes
Sirius
0.0
1.0
2.0
3.0
4.0
5.0
Open cluster
Globular cluster
Diffuse nebula
Planetary nebula
Galaxy

S	M	T	W	T	F	S
●					●	2
3	4	5	6	7	8	◐
10	11	12	13	14	15	16
○	18	19	20	21	22	23
◑	25	26	27	28	29	30

EST

4 Quadrantid meteor shower peaks

5 **10 a.m.**
The moon passes 0.2° north of Regulus

8 **5 p.m.**
Mars passes 4° north of Spica (morning)

9 **3 p.m.**
The moon passes 3° north of Mars

19 **3 a.m.**
The moon passes 2° north of Venus

21 **6 p.m.**
The moon passes 1.8° south of Jupiter

22 **3 a.m.**
Neptune is in conjunction with the sun

24 **1 a.m.**
The moon passes 2° south of Saturn

27 **2 a.m.**
The moon passes 0.5° north of Aldebaran

Events in **red** are ones you won't want to miss. All times in the calendars are eastern time. "Morning" or "evening" at the end of a listing denotes that the event appears before sunrise or after sunset, respectively.

FEB

A Dazzling Evening Duo

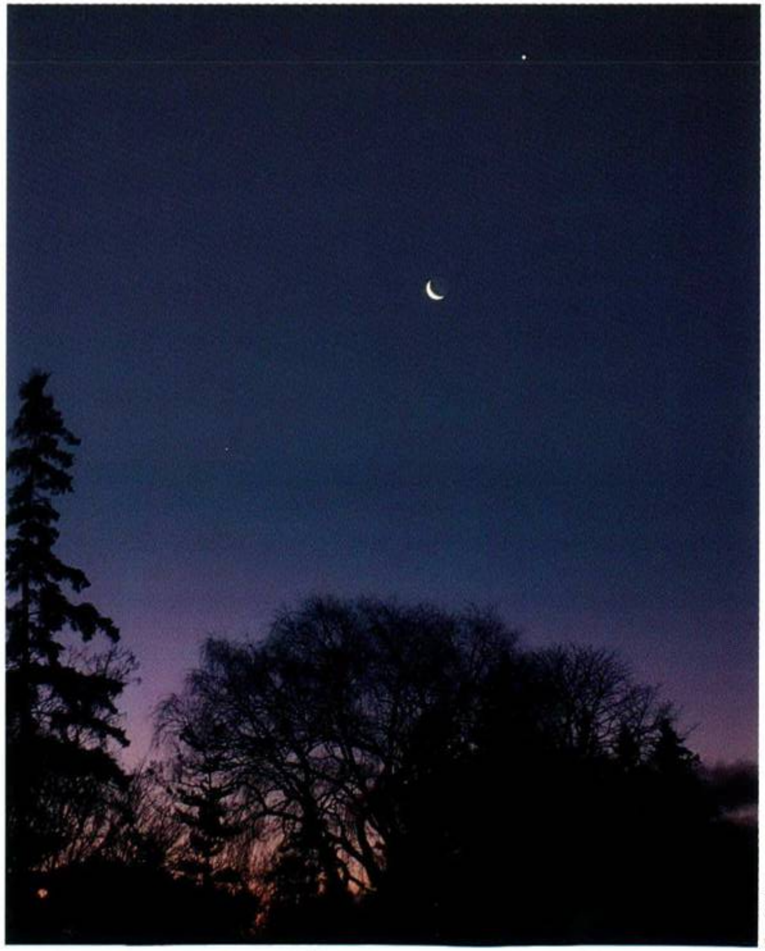
When two brilliant planets appear near each other in the sky, it always ranks as one of the memorable sights of the year. Venus and Jupiter, the two brightest planets, team up this month in a grand spectacle, ending February within the same field of view in a telescope even though nearly 400 million miles of space separate them. It all begins with Venus and Jupiter standing some 22° apart as darkness falls on the evening of February 1. Jupiter lies on the far side of the sun from Earth and is sliding toward conjunction while Venus is climbing away from the solar glare toward its greatest eastern elongation in June.

During the ensuing 22 days of February the two planets move approximately 1° closer per day. A striking crescent moon joins the duo, gliding by on February 17 and 18. This three-week build-up culminates on February 23 when the two planets appear less than 10" apart. The pair of planets pops into view soon after sunset and, as twilight darkens, the dazzling double planet begins to dominate the sky. It's a stunning sight with Jupiter shining at magnitude –2.1 and Venus nearly six times brighter than that at magnitude –4.0.

Through a telescope both planets appear in the same eyepiece field of view. Notice the similar phases of the two planets — Jupiter is fully illuminated while Venus exhibits an 89 percent illumination. More noticeable is the difference in their apparent sizes, with Jupiter's disk measuring 33.9" across the equator and Venus sporting an 11.6"-diameter disk.

This conjunction takes place near the circlet asterism in Pisces the Fish, while high above the pair, 0.3-magnitude Saturn watches over the action. Below the Jupiter-Venus hook-up lies –1.0-magnitude Mercury. The alignment is just an apparent one of course. If we could view the solar system from above, the two planets would appear nowhere near each other. In fact, from Earth Venus lies 133 million miles away while Jupiter is a distant 540 million miles away.

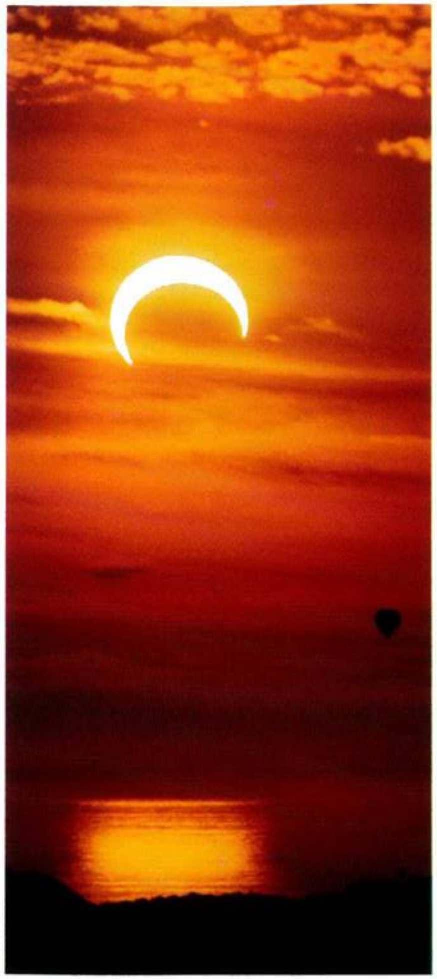
Since 1950, there have been 20 occasions in which Jupiter and Venus have come within 0.5° of each other, though not all have been visible during darkness. Only two of those conjunctions compare to this close alignment: those in 1956 and 1980. And those occurred with the planets in the morning sky, so this is the planets' best evening conjunction in more than 50 years.



Gary Collver

A crescent moon slides between Venus (above) and Jupiter on the morning of December 29, 1994.

Ringed Sun in Australia


H. J. P. Arnold

An annular eclipse of the sun crosses the southern Indian Ocean and Australia on February 16. Annular eclipses occur when the moon lies too far from Earth to completely cover the sun's bright photosphere. At mideclipse, rather than seeing the corona as in a total eclipse, a bright ring of sunlight remains visible. This ring of light, or "annulus," gives the eclipse its name.

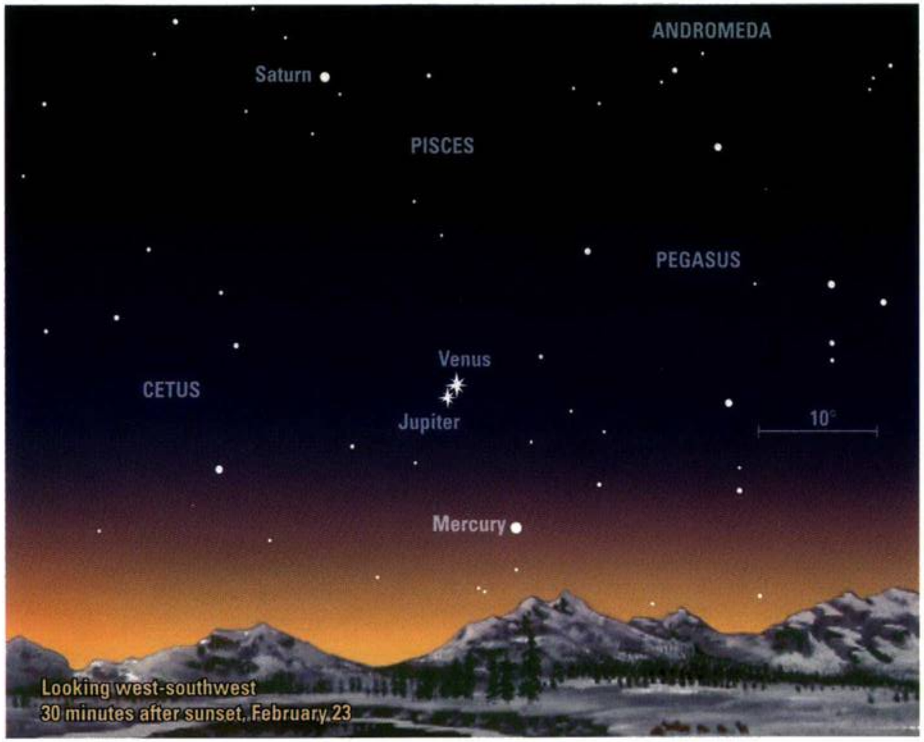
This eclipse occurs in the late afternoon for the antipodeans, with the track crossing Australia from a point just north of Perth in Western Australia through the great desert to a point north of Townsville in Queensland. The rest of Australia, the southern part of Africa, Antarctica, and Indonesia experience a partial solar eclipse.

Unlike a total eclipse, which can be viewed without danger, watching an annular or partial eclipse requires caution. Just a tiny sliver of the photosphere can damage your eyes. To view this eclipse directly, you must use a good solar filter. Or view indirectly by projecting an image of the sun onto a piece of white cardboard.

A partially eclipsed sun sinks toward the Pacific Ocean during the annular eclipse of January 4, 1992.

CONJUNCTIONS BETWEEN THE MOON AND PLANETS IN 1999

Date	Planet	Time best seen	Date	Planet	Time best seen
January 21	Jupiter	evening	June 16	Venus	evening
January 23	Saturn	evening	July 15	Venus	evening
February 17	Venus	evening	October 24	Jupiter	all night
February 17	Jupiter	evening	October 25	Saturn	all night
March 19	Saturn	evening	November 4	Venus	morning
April 29	Mars	all night	December 12	Mars	evening



Looking west-southwest
30 minutes after sunset, February 23

S	M	T	W	T	F	S
	1	2	3	4	5	6
7	◐	9	10	11	12	13
14	15	○	17	18	19	20
21	◑	23	24	25	26	27
28						

EST

1 **8 p.m.**
The moon passes 0.3° north of Regulus
9 p.m.
Uranus is in conjunction with the sun

3 **midnight**
Mercury is in superior conjunction

4 **3 a.m.**
Vesta is at opposition

6 **11 p.m.**
The moon passes 3° north of Mars

14 **7 a.m.**
The moon passes 1.5° north of Neptune

16 **2 a.m.**
Annular solar eclipse (visible in Australia and the Indian Ocean)

18 **1 a.m.**
The moon passes 1.8° south of Venus
11 a.m.
The moon passes 2° south of Jupiter

20 **10 a.m.**
The moon passes 3° south of Saturn

23 **8 a.m.**
The moon passes 0.4° north of Aldebaran
4 p.m.
Venus passes 0.1° north of Jupiter (evening)

MAR

Mercury's Best Show of the Year

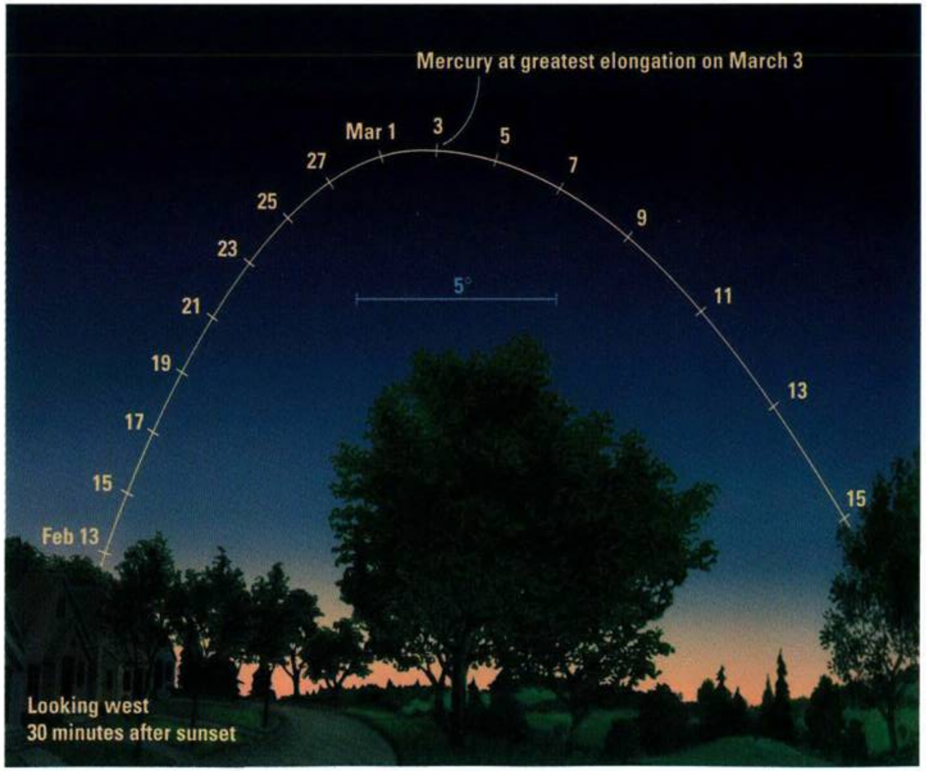
As a child did you play hide-and-seek and always lose? That's what it's like trying to spot Mercury. The very moment Mercury gets far enough away from the sun to be easily visible in a dark sky, it slinks back into the solar glare again. Its 36-million-mile orbital distance from the sun means that Mercury never strays far from its brilliant parent as seen from Earth.

Combine this with the fact that at every eastern elongation Mercury appears brightest before it reaches its maximum distance from the sun and fades as the angular distance increases, and you can begin to realize how elusive Mercury truly is. The change in brightness is a combination of factors. Even though Mercury gets closer to Earth as greatest eastern elongation approaches, its phase shrinks rapidly. The phase is the dominant factor in Mercury's brightness.

The best times to catch Mercury occur when the ecliptic makes a steep angle to the horizon either before sunrise or after sunset, placing Mercury at the maximum height above the horizon. This occurs in the evening during springtime and in the mornings during autumn.

This year the best evening apparition for Mercury comes in late February and early March. Greatest elongation occurs on March 3, when the elusive planet lies 18° east of the sun, placing it relatively high in the evening sky shortly after sunset. Adding to this treat is the nearby planet Venus, shining brilliantly at magnitude –4.0, and –2.1-magnitude Jupiter. Jupiter and Venus have just passed a stunning close conjunction last month and dominate the evening sky so much that Mercury risks being forgotten.

Mercury's trick to capture attention is to swing up toward Jupiter, passing 4° to the northwest (lower right) of the giant planet on March 6. In the bright twilight of this late winter evening, Mercury's respectable magnitude of 0.3 helps it put on a fine show. Observers with telescopes will be treated to a view of a crescent planet just 32 percent illuminated and measuring 8" across, a quarter the apparent size of Jupiter.



However, since Mercury never lies far above the horizon, views through a telescope are inherently tricky, often marred by the excessive turbulence of early evening heat. If you watch Mercury over the next week or so you will see its phase shrink even further. Remember that this alignment between Mercury and Jupiter is a line-of-sight effect only. Mercury is comparatively nearby, at 0.8 astronomical unit from Earth, while Jupiter is a distant 5.9 AU from us.

Search for the Young Moon's Glow

Few naked-eye sights can surpass the beauty of a slender crescent moon hanging amidst the pink, red, and purple colors of a twilight sky. The best time this year to spot such a crescent in the evening sky comes during the middle of March.

Early spring is prime time for observing the lunar crescent because the ecliptic – the apparent path of the sun and moon across the sky – makes a steep angle to the western horizon after sunset. That means the angular separation between the moon and the sun translates mostly into altitude above the horizon.

The moon reaches its new phase, passing between the sun and Earth, during daylight on March 17. Unfortunately, after the sun sets that night, the moon still lies too close to the sun to be glimpsed. By the following evening, however, it will be nicely positioned for viewing. Head outside 30 minutes after sunset and look toward the west: The moon will be just 2 percent lit and suspended a scant 10° high in the twilight. (Ten degrees is about the angle subtended by your closed fist when held at arm's length.) With each passing evening, the moon will appear higher in the west and have a greater percentage of its disk illuminated.

Be sure to look carefully at the unlit part of the moon. You should see a faint illumination, called earthshine, playing across the dark lunar surface. This comes about because whenever the moon shows a crescent phase, the moon "sees" a nearly full Earth. Because Earth is both bigger and more reflective than the moon, lots of light reaches the moon's surface to be reflected back in our direction.

George Livadaras

March offers a great chance to spy the slim crescent of a young moon, which looks like the old moon seen here.

Mercury
NASA/JPL

WHEN TO SEE MERCURY IN 1999

EVENING

Greatest elongation	Visible from	Peak altitude
March 3	Feb. 16 to Mar. 12	11°
June 28	June 2 to July 28	11°
October 24	Sep. 20 to Nov. 10	4°

MORNING

Greatest elongation	Visible from	Peak altitude
April 16	Mar. 27 to May 18	4°
August 14	Aug. 4 to Aug. 31	10°
December 2	Nov. 22 to Dec. 30	12°

S	M	T	W	T	F	S
	1	●	3	4	5	6
7	8	9	◐	11	12	13
14	15	16	○	18	19	20
21	22	23	◑	25	26	27
28	29	30	●			

EST

1 **5 a.m.**
The moon passes 0.2° north of Regulus

3 **8 a.m.**
Mercury is at greatest eastern elongation (18°, evening)

6 **9 p.m.**
The moon passes 3° north of Mars

13 **6 p.m.**
The moon passes 1.4° north of Neptune

14 **3 p.m.**
The moon passes 1.3° north of Uranus

18 **6 a.m.**
The moon passes 3° south of Jupiter

19 **2 p.m.**
Mercury is in inferior conjunction

8 p.m.
The moon passes 5° south of Venus

10 p.m.
The moon passes 3° south of Saturn

20 **4 p.m.**
Venus passes 3° north of Saturn (evening)

9 p.m.
Equinox (northern spring/southern autumn begins)

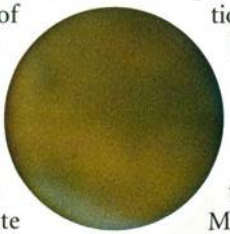
22 **1 p.m.**
The moon passes 0.6° north of Aldebaran

28 **11 a.m.**
The moon passes 0.3° north of Regulus

APR

A Martian Invasion

The year 1999 may be remembered as the year of Mars, and excitement will build as Mars grows brighter in our skies. Mars fever begins with the January launch of the Mars Surveyor 98 Lander, due to land on Mars's south polar cap in December. That's followed by the long-awaited arrival of Mars Global Surveyor in its final orbit, when it will begin detailed mapping of the martian surface at the unprecedented resolution of only a few feet. In addition, the Mars Climate Orbiter should arrive in orbit around the Red Planet in September.



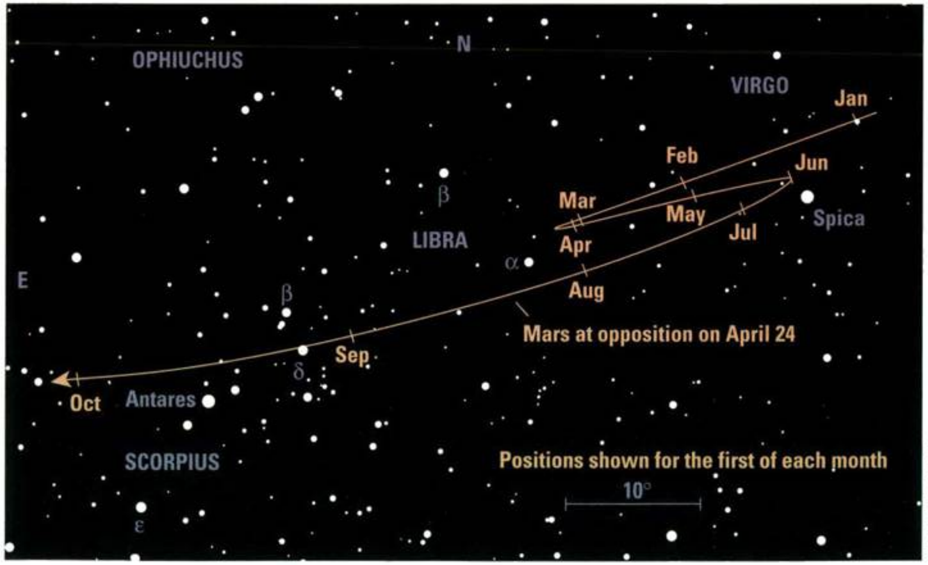
Throw in the best opposition of Mars in nine years, which occurs on April 24, and Mars in springtime is about as good as it gets. The Red Planet shines brilliantly at magnitude –2.1 at opposition and will remain above zero magnitude from late February until late July.

Mars comes to opposition only once every two years. Because Mars's orbit is fairly elliptical, however, not all oppositions are equal. The best opposition dates occur when Mars is also near perihelion, when the Red Planet can approach to within 35 million miles of Earth. This happens when Mars is also well south of the celestial equator — not a good situation for observers in the Northern Hemisphere because Mars then stays fairly close to the horizon.

The next such perihelic opposition occurs in 2003, when Mars will rival Jupiter in brilliance. The 2001 opposition will also be a very good one, but for Northern Hemisphere observers Mars will remain low as it crosses the southernmost part of Ophiuchus.

So join in the martian festivities this year. In January Mars lies to the north of Spica in the constellation Virgo the Maiden. It starts the year 139 million miles from Earth shining at magnitude 1.0, the same brilliance as the white gem, Spica.

By March its easterly path halts just short of Alpha (α) Librae. As Earth begins to overtake its planetary neighbor, Mars follows a retrograde or westerly path. By mid-March its distance has practically halved to 73 million miles and it has brightened to magnitude –0.5.



Positions shown for the first of each month

Photo by Donald Parker

With a diameter of just 4,200 miles, Mars always appears tiny through a telescope, so we are limited to seeing any detail on the planet to the few weeks either side of opposition. Observers should seize this chance to view a decent-size disk of Mars, which by mid-March has grown to an angular size of 12". This is still tiny in comparison to Jupiter, but appreciable detail on Mars can be seen once the planet gets above 10". Mars will spend from late February to mid-July above that size, reaching a maximum of 16.2" at closest approach. The closest Mars can ever get to Earth is 35 million miles, and that will occur in 2003; for 1999 we'll have to settle for 54 million miles. Still, it will serve as a great warm-up for the next few years of martian delights, both from the armada of spacecraft heading its way and telescopic observation from Earth.

Exploring the Spring Sky

The Big Dipper, our signpost in the sky, swings high overhead during the spring and lies near the center of our chart. This season of rejuvenation encourages us to move outdoors with the milder temperatures, and with it a new set of stars beckons us.

Follow the arc of stars outlining the handle of the Dipper away from the bowl and you will land on brilliant Arcturus. This orangish star dominates the spring sky in the kite-shaped constellation Bootes. Well to the west of Bootes lies Leo the Lion. You can find its brightest star, Regulus, by using the pointers in the Dipper in reverse. Regulus lies at the base of a group of stars shaped like a backward question mark, which represents the head of the lion.

Midway between Regulus and Pollux in Gemini, which is now sinking in the west, is the diminutive group Cancer the Crab. Centered in the group is a hazy patch of light that binoculars reveal as the Beehive star cluster (M44).

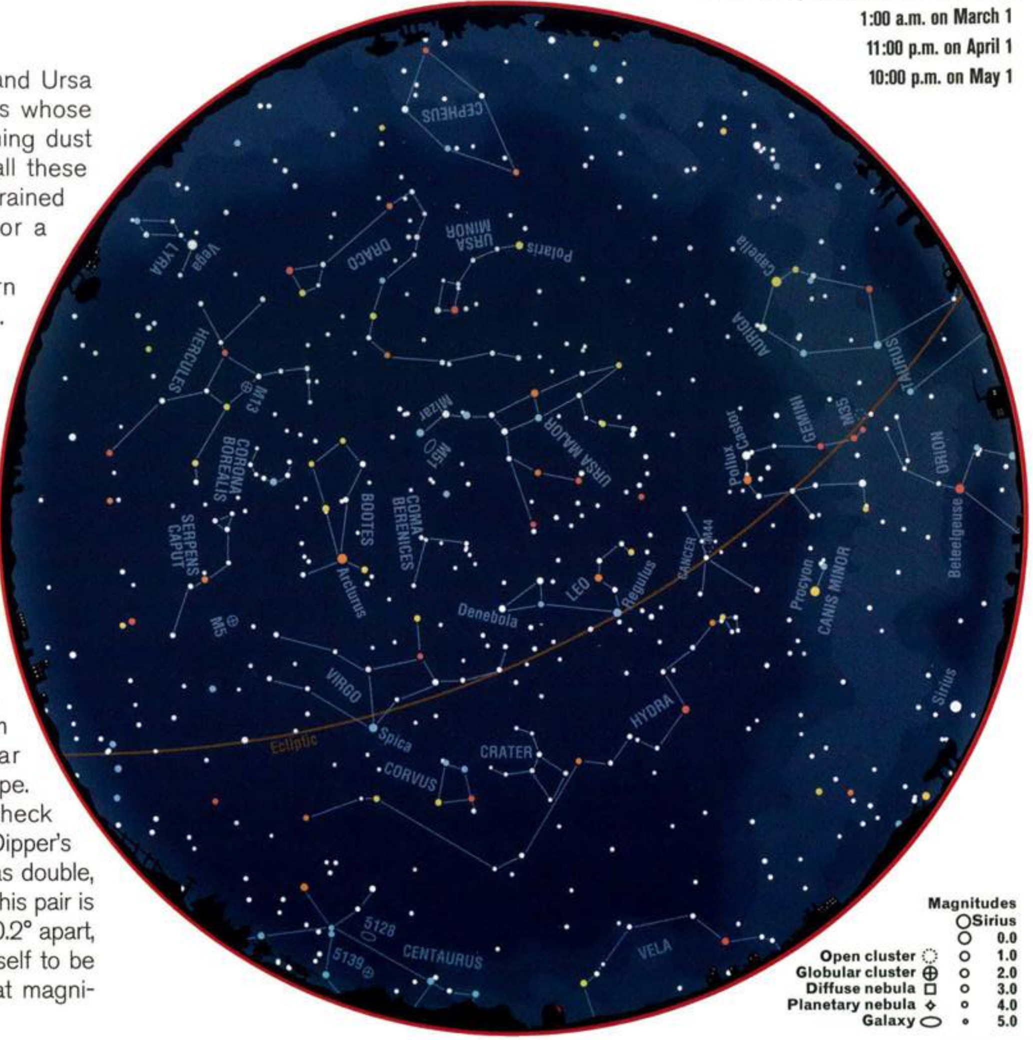
To the southeast of Leo is the realm of the galaxies and the constellation Virgo the Maiden. Virgo's brightest star, Spica, shines at magnitude 1.0.

During springtime the Milky Way lies level with the horizon, and it's easy to realize that we are looking out of the plane of our galaxy. In the direction of Virgo, Leo, Coma Berenices, and Ursa Major lie hundreds of galaxies whose light is unhindered by intervening dust in our own galaxy. However, all these galaxies are elusive to an untrained eye and require binoculars or a telescope to be seen.

Bootes lies on the eastern border of this galaxy haven. Midway between Arcturus and Vega, the bright "summer" star rising in the northeast, is a region where no star shines brighter than 2nd magnitude. A semicircle of stars represents Corona Borealis, and adjacent to it is a large region that houses Hercules, the fifth-biggest constellation in the sky. It's here we can find the northern sky's brightest globular cluster, M13. A naked-eye object from a dark site, it is spectacular when viewed through a telescope.

Returning to Ursa Major, check the second-to-last star in the Dipper's handle. Most people will see it as double, while binoculars show it easily. This pair is called Mizar and Alcor. They lie 0.2° apart, and a telescope shows Mizar itself to be double. Its companion shines at magnitude 4.0 and is 14" from Mizar.

The all-sky map shows how the sky looks at
1:00 a.m. on March 1
11:00 p.m. on April 1
10:00 p.m. on May 1


CEPHEUS
LYRA
Vega
DRACO
URSA MINOR
Polaris
Capella
AURIGA
HERCULES
M13
CORONA BOREALIS
SERPENS CAPUT
M5
Mizar
M51
URSA MAJOR
BOOTES
COMA BERENICES
Arcturus
Denebola
LEO
Regulus
CANCER
M44
Pollux
Castor
GEMINI
M35
TAURUS
ORION
Betelgeuse
Procyon
CANIS MINOR
Sirius
HYDRA
VIRGO
Spica
Ecliptic
CRATER
CORVUS
5128
5139
CENTAURUS
VELA
Magnitudes
Sirius
0.0
1.0
2.0
3.0
4.0
5.0
Open cluster
Globular cluster
Diffuse nebula
Planetary nebula
Galaxy

S	M	T	W	T	F	S
				1	2	3
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11	12	13	14	15	○	17
18	19	20	21	◑	23	24
25	26	27	28	29	●	

EDT

1 **1 a.m. (EST)**
Jupiter is in conjunction with the sun

3 **3 a.m. (EST)**
The moon passes 3° north of Mars

10 **5 a.m.**
The moon passes 1.1° north of Neptune

11 **3 a.m.**
The moon passes 1.0° north of Uranus

13 **midnight**
The moon passes 1.1° south of Mercury

16 **noon**
Mercury is at greatest western elongation (28°, morning)

18 **5 p.m.**
The moon passes 7° south of Venus

10 p.m.
The moon passes 0.7° north of Aldebaran

20 **7 p.m.**
Pallas is in conjunction with the sun

21 **4 p.m.**
Venus passes 7° north of Aldebaran (evening)

22 Lyrid meteor shower peaks

24 **2 p.m.**
Mars is at opposition

5 p.m.
The moon passes 0.5° north of Regulus

27 **7 a.m.**
Saturn is in conjunction with the sun

29 **5 p.m.**
The moon passes 4° north of Mars

MAY

Pluto: Most Distant Once Again

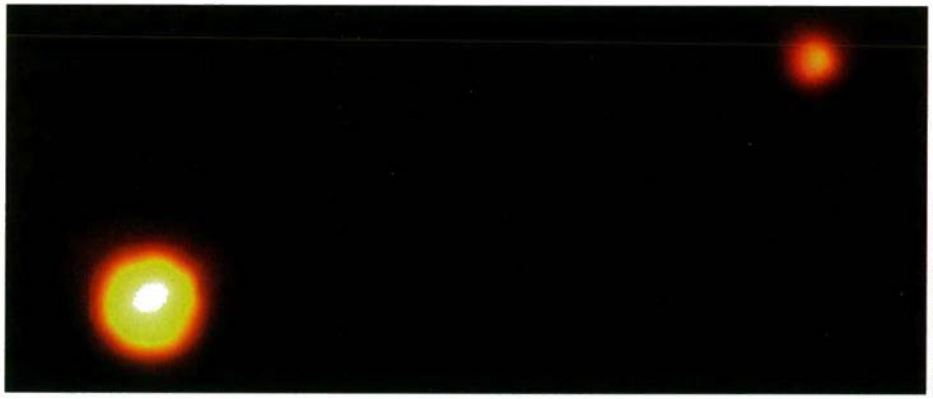
"What's the farthest planet from the sun?" Since 1979 generations of students have used this question to catch their buddies. In that year Pluto's highly eccentric orbit brought the tiny planet closer to the sun than Neptune. The two planets can never collide, fortunately, because Pluto's orbit is inclined to the ecliptic at a solar system high of 17°.

Well, after a 20-year stint, this February Pluto returned to its rightful place as the most distant planet from the sun. This will provide a few more years of students trying to catch each other having to remember that Pluto is now the distance champion and will be for the next 228 years.

And how our knowledge of this tiny planet has changed since 1979. The planet's moon Charon, discovered in 1978 and the largest satellite relative to its parent in the solar system, began a series of occultations with Pluto during the 1980s that allowed various albedo features to be mapped on Pluto's surface. These features have since been confirmed by the superior resolution of the Hubble Space Telescope.

From the size and period of Charon's orbit, Pluto's mass could be determined accurately for the first time. Pluto weighs in at just 0.003 times Earth's mass. And its small size — it's just 1,485 miles across — has brought into question Pluto's standing as a full-fledged planet. The debate continues today. Is Pluto simply the brightest of the Kuiper Belt objects, a family of small, icy objects that orbit the sun in the nether reaches of the solar system? Dozens of these bodies have been discovered this decade. Or maybe Pluto was once a moon of Neptune, perhaps similar to Triton, that got knocked out of its orbit by a collision?

With these fascinating questions and details in our mind, this year we can track down Pluto as it makes a rare close pass of a bright star. At magnitude 2.6, Zeta (ζ) Ophiuchi is an easy star to find. It lies 16° due north of the ruddy 1st-magnitude star Antares in Scorpius. It's also the middle star at the base of the large kite-shaped constellation Ophiuchus the Serpent-Bearer, lying midway between Delta (δ) and Eta (η) Ophiuchi.



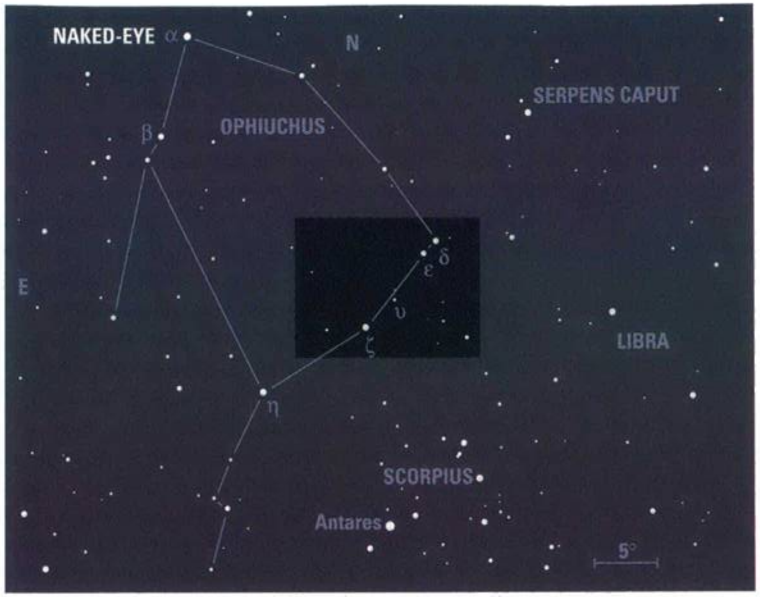
R. Albrecht (ESA/ESO) and NASA

Pluto (left) and Charon are the closest thing to a double planet in the solar system, though only HST can see this much detail.

Pluto lies closest to Zeta on January 3, but that's not the best time to try to spot the 14th-magnitude planet. Not only will the glare from the bright star interfere, but the two objects then lie low in the morning twilight. Any lucky observer about 165,000 miles south of the ecliptic on this date could see Pluto actually occult Zeta Ophiuchi.

However, by May when Pluto reaches opposition, it lies just a fraction of a degree north of Zeta. You'll have to take care to move bright Zeta out of the field of view when trying to spot Pluto, and you'll need at least an 8-inch scope to do it reliably. Once you identify the correct star field, it's best to use high magnification to zero in on Pluto.

Try to track down Pluto this year. As Pluto continues to head south over the next few decades, viewing from the Northern Hemisphere is only going to worsen. (Not to mention the fact that the dim planet will be traversing the rich starfields of the Milky Way.) And it's not often that a bright star is there to guide you. By October Pluto will have swung south of Zeta, and the 10th-magnitude asteroid Juno will casually pass between Zeta and Pluto during that month.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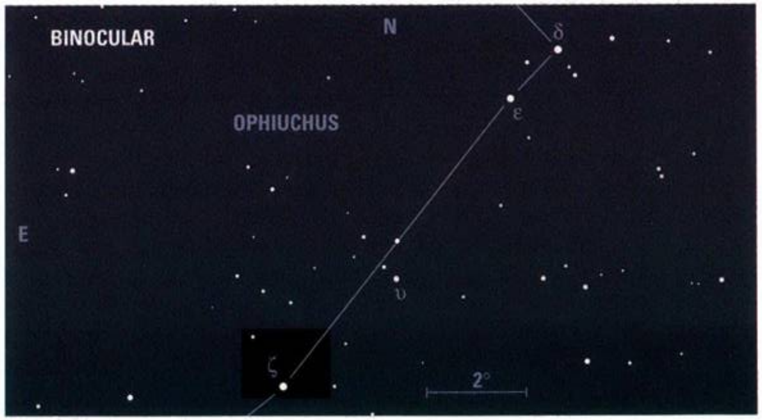
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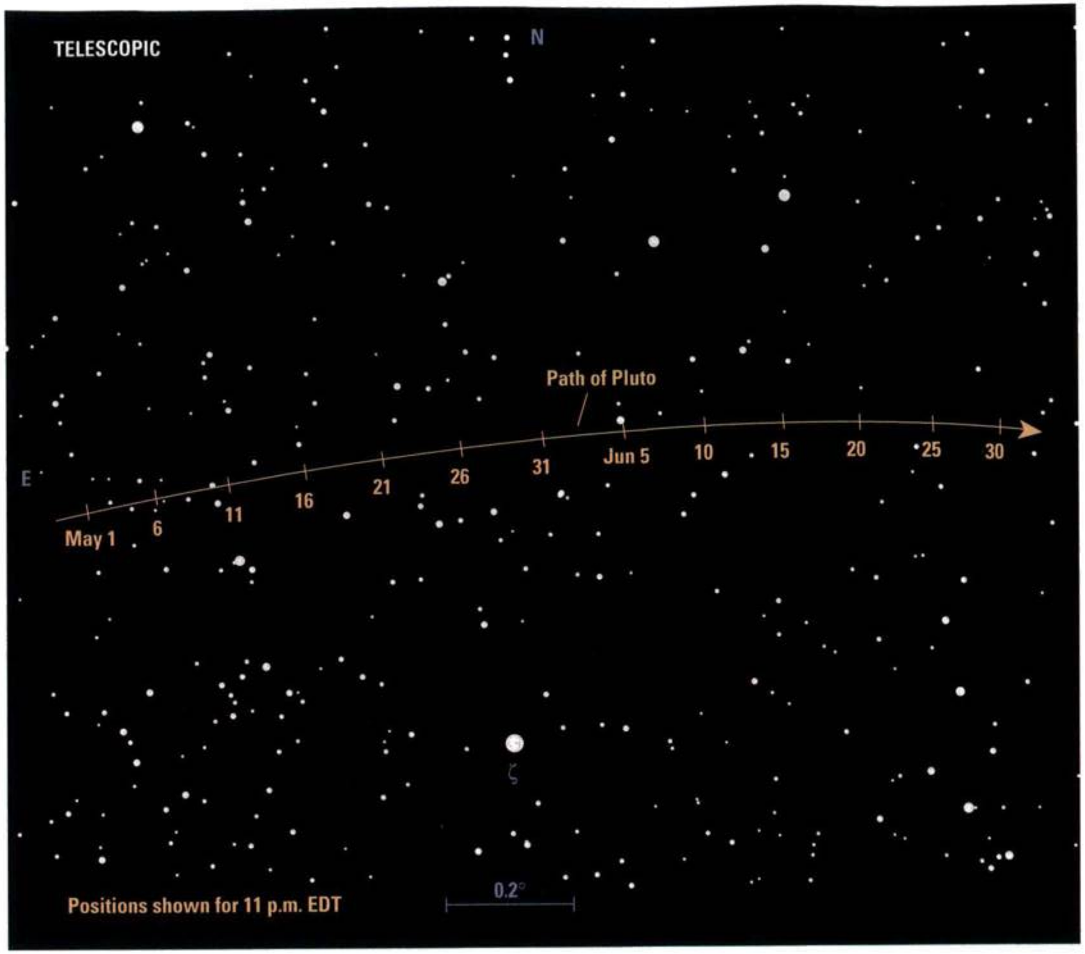
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Path of Pluto
E
May 1
6
11
16
21
26
31
Jun 5
10
15
20
25
30
ζ
Positions shown for 11 p.m. EDT
0.2°

S	M	T	W	T	F	S
●	31					1
2	3	4	5	6	7	◐
9	10	11	12	13	14	○
16	17	18	19	20	21	◑
23	24	25	26	27	28	29

EDT

1 **6 a.m.**
Mercury passes 1.7° south of Jupiter (morning)
1 p.m.
Mars comes closest to Earth

5 Eta Aquarid meteor shower peaks

7 **1 p.m.**
The moon passes 0.9° north of Neptune

8 **noon**
The moon passes 0.7° north of Uranus

13 **1 a.m.**
The moon passes 4° south of Jupiter
2 p.m.
Mercury passes 0.7° north of Saturn (morning)

16 **9 a.m.**
The moon passes 0.9° north of Aldebaran

18 **11 a.m.**
The moon passes 6° south of Venus

21 **11 p.m.**
The moon passes 0.7° north of Regulus

25 **2 p.m.**
Mercury is in superior conjunction
3 p.m.
Juno is at opposition

26 **7 a.m.**
The moon passes 5° north of Mars

30 **6 p.m.**
Venus passes 4° south of Pollux (evening)
8 p.m.
Pluto is at opposition

JUN

Brilliant Venus Conquers the Evening

Venus, known since time immemorial as the morning star or the evening star depending on which side of the sun it happens to be on, is easily the brightest planet in the sky. It can even cast a shadow under the right conditions. The reason is that Venus is cloaked in a thick, opaque atmosphere that reflects 65 percent of the sunlight that hits it, more than any other planet. Venus spends most of the year in the evening sky as a stunning object. The year opens with Venus moving away from the sun as it progresses along the far side of its orbit trying to catch up with Earth — a race it always wins.

In the first three months of the year, Venus passes four planets, two of them bright. On January 5 it passes 1.7° south of Neptune, then 0.9° south of Uranus eight days later. Both conjunctions occur low in the evening twilight and neither Uranus nor Neptune glows very brightly; you might be able to glimpse the Uranus conjunction with binoculars.

Watch as Venus climbs higher in the sky each evening and begins to catch up with Jupiter very quickly. On February 23 Venus and Jupiter have a very close conjunction, just one-tenth of a degree apart, or only one-fifth of the moon's diameter. This stunning pairing is the best conjunction of the year. Both will be visible in the same telescopic field of view, with Venus showing an 89-percent-illuminated and featureless disk while Jupiter will be full of its usual atmospheric plumage. As the pair are closing, a fine, slender crescent moon passes beneath them on February 17 and 18.

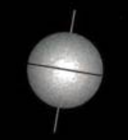
Venus continues to pull away from the sun and is by now in a dark sky trying to catch up to Saturn, which it does on March 20. While not as close as the Jupiter encounter, Saturn and Venus will be separated by just 3°. The pair sets more than two-and-a-half hours after the sun, placing them in a very dark sky.

Venus's climb from the sun is far from over, however, and it continues to pass in front of interesting objects as it does so. The planet passes 3° south of the Pleiades on April 11, then moves to midway between the horns of Taurus the Bull on May 2. After traversing Gemini during May, Venus passes just north of the Beehive Cluster, M44 in Cancer the Crab, on June 12 and is joined by a slender crescent moon on the 16th. Venus reaches greatest eastern elongation on June 11 when it appears 50 percent illuminated, lies 45° from the sun, and sets three hours after our star.

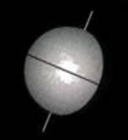
Following its lengthy ascent into the evening sky, Venus performs what is comparatively a very hasty descent toward the horizon combined with a rapid motion south in declination. It passes just 1° from Regulus in Leo the Lion on July 11, when its illuminated phase has shrunk to 30 percent. By the end of July it will appear as a slender crescent just 12 percent illuminated, and it sets just one hour after the sun. Solar conjunction occurs on August 20, after which Venus passes into the morning sky for the remainder of the year. By September the growing crescent of Venus rises before Leo, and after passing south of Regulus once again, the brilliant morning star reaches its greatest western elongation from the sun (46° away) as October draws to a close.

Jim Baumgardt

A crescent Venus sinks toward the mountains a few weeks before it will reach solar conjunction.



January 1, 1999
Disk size = 10.2"
Magnitude = −3.9



March 1, 1999
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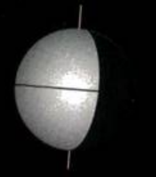
Magnitude = −4.0



May 1, 1999
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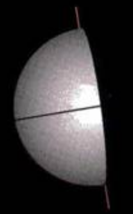
Magnitude = −4.1



June 1, 1999
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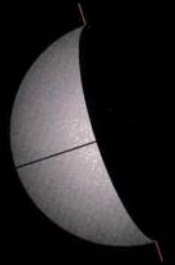
Magnitude = −4.2



July 1, 1999
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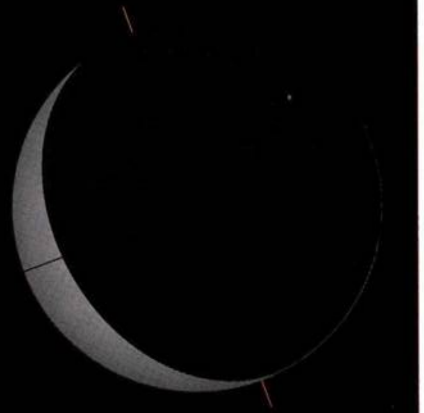
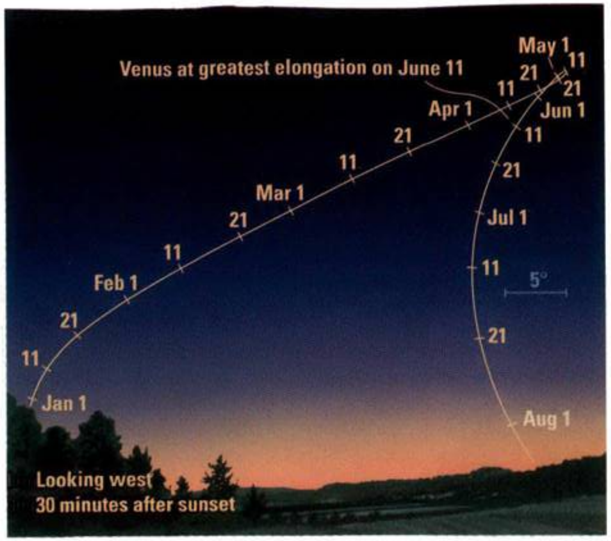
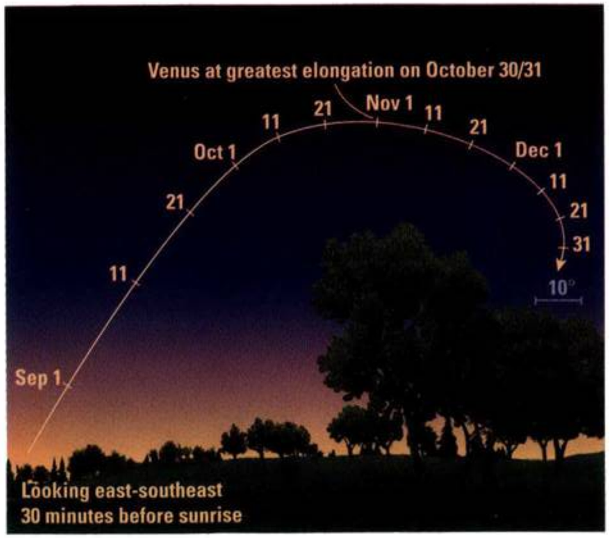
Magnitude = −4.4



August 1, 1999
Disk size = 48.9"
Magnitude = −4.4


Venus at greatest elongation on June 11
May 1
11
21
21
11
Jun 1
Apr 1
11
21
21
11
Jul 1
Mar 1
21
11
11
5°
Feb 1
21
21
11
Jan 1
Aug 1
Looking west
30 minutes after sunset


Venus at greatest elongation on October 30/31
Nov 1
21
11
11
21
Oct 1
Dec 1
11
21
21
31
11
10°
Sep 1
Looking east-southeast
30 minutes before sunrise

S	M	T	W	T	F	S
		1	2	3	4	5
6	◐	8	9	10	11	12
○	14	15	16	17	18	19
◑	21	22	23	24	25	26
27	●	29	30			

EDT

3 **6 p.m.**
The moon passes 0.7° north of Neptune

4 **6 p.m.**
The moon passes 0.5° north of Uranus

9 **8 p.m.**
The moon passes 4° south of Jupiter

10 **10 p.m.**
The moon passes 3° south of Saturn

11 **8 a.m.**
Venus is at greatest eastern elongation (45°, evening)

15 **4 a.m.**
The moon passes 4° south of Mercury

16 **11 p.m.**
The moon passes 2° south of Venus

18 **7 a.m.**
The moon passes 1.0° north of Regulus

21 **2 p.m.**
Mercury passes 5° south of Pollux (evening)

4 p.m.
Solstice (northern summer/southern winter begins)

22 **4 p.m.**
The moon passes 6° north of Mars

28 **7 p.m.**
Mercury is at greatest eastern elongation (26°, evening)

30 **11 p.m.**
The moon passes 0.6° north of Neptune

JUL

A Trio of Worthy Eclipses

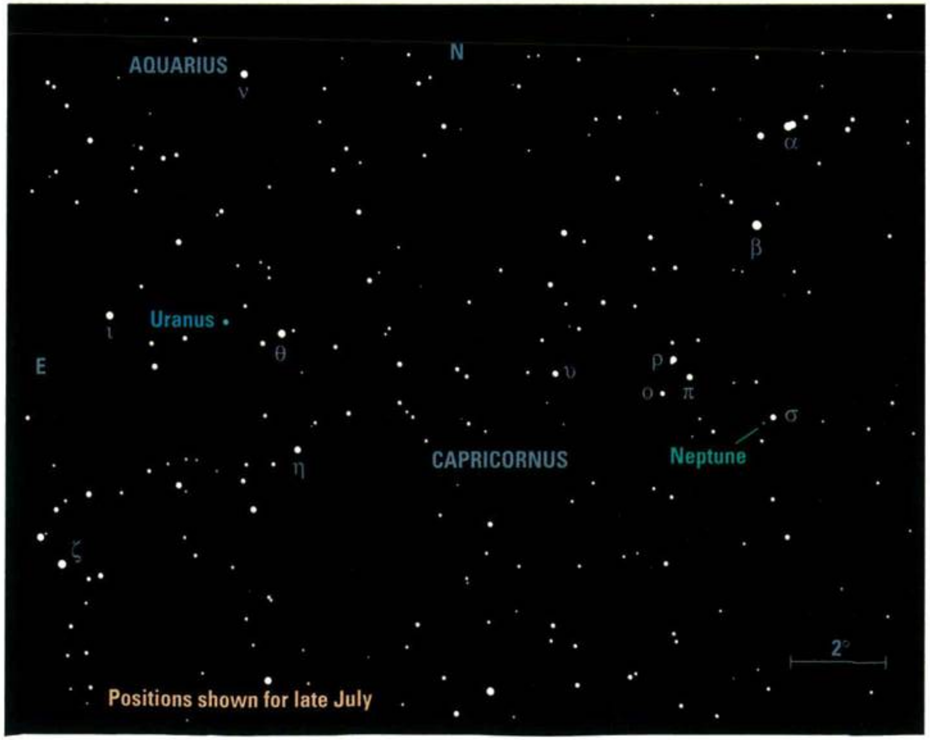
The moon regularly passes in front of, or occults, stars on its monthly path around Earth. Viewing such occultations through a telescope provides a reminder, as if one were needed, that the moon lies closer to us than the stars. Precise timing of such events provides astronomers with accurate positions of the moon in its orbit, and over the decades it can provide valuable statistical data regarding any changes in the moon's orbit.

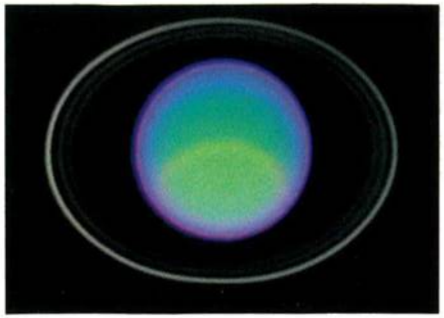
Much less frequent are lunar occultations of the planets. Yet this month sees two of them, occurring just one day apart. In the early morning hours of July 28 the full moon passes in front of Neptune for observers throughout the United States. The time depends on your exact location, but it occurs at roughly 4 a.m. EDT (3 a.m. CDT, 2 a.m. MDT, and 1 a.m. PDT).

About 23 hours later (again depending on your exact location), the moon occults Neptune's twin, Uranus, though this event can only be seen from south of a line that stretches from eastern Canada to San Diego.

But let's go back to the Neptune event for a moment. Less than two hours after the reappearance of Neptune from behind the moon's limb, the moon passes into Earth's shadow, marking the beginning of this year's only partial lunar eclipse visible from the United States. Continuing our occultation theme, if there were any observers on the moon, they would see Earth occulting, or eclipsing, the sun.

Back on Earth, for cities in the Midwest the moon will set while still in eclipse. Lucky observers in certain high mountain peaks in the Rockies with good views to both the east and west may be able to see the eclipsed moon on one horizon while the sun rises on the opposite horizon. Observers farther west will see the entire eclipse, which reaches a maximum at 4:34 a.m. PDT when 40 percent of the moon is immersed in Earth's shadow. East coast observers will only see the early penumbral stages of the eclipse before dawn interferes.





E. Karkoschka and NASA; Above: H. Hammel and NASA

Exploring the Summer Sky

The richness of the summer sky is exemplified by the splendor of the Milky Way. Stretching from the northern horizon in Perseus, through the cross-shaped constellation Cygnus overhead, and down to Sagittarius in the south, the Milky Way is packed with riches. These riches include star clusters, nebulae, double stars, and variable stars.

Let's start with the Big Dipper, our perennial stellar signpost, which now lies in the northwest with its handle still pointing toward Arcturus. High overhead, and the first star to appear after sunset, is Vega in Lyra the Harp. Vega forms one corner of the summer triangle, a familiar asterism of three stars. Near Vega is the famous double-double, Epsilon (ε) Lyrae. Two 5th-magnitude stars lie just over 3' apart and can be split in binoculars. Each of these two stars is also double, but you need a telescope to split them.

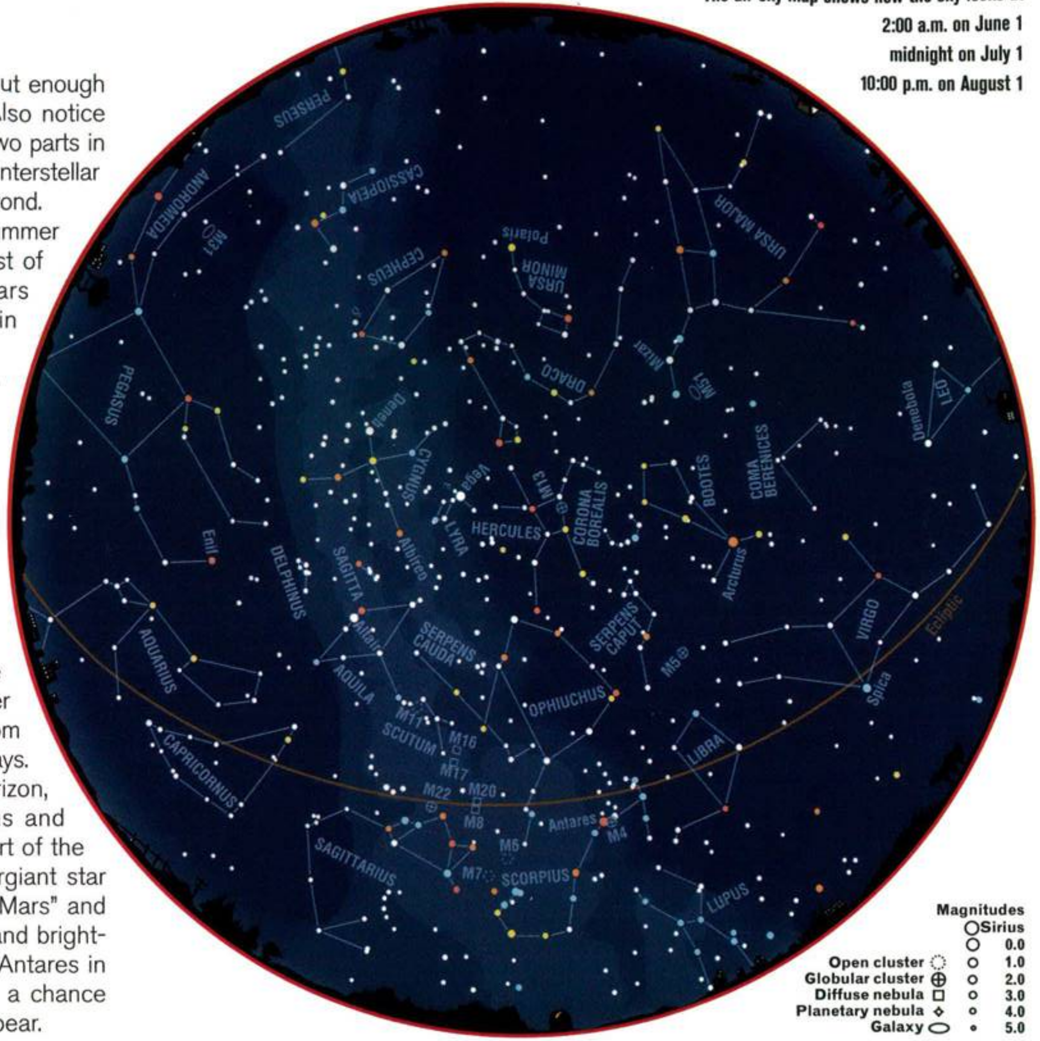
To the east of Vega lies the triangle's second star: Deneb in Cygnus the Swan (some see a cross in this pattern). Deneb marks the tail of this graceful bird, the cross represents its outstretched wings, and the base of the cross denotes its head, which is marked by the incomparable double star Albireo – a match of a 3rd-magnitude yellow star and a 5th-magnitude blue star offering the finest color contrast anywhere in the sky. Deneb is a supergiant star pumping out enough light to equal 60,000 suns. Also notice that the Milky Way splits into two parts in Cygnus, a giant rift caused by interstellar dust blocking starlight from beyond.

Altair, the third star of the summer triangle, is the second brightest of the three. Lying 17 light-years away, it's the brightest star in Aquila the Eagle.

Frequently overlooked to the north of Deneb lies the constellation Cepheus the King. Shaped rather like a bishop's hat, the southern corner of Cepheus is marked by a compact triangle of stars including Delta (δ) Cephei. This famous star is the prototype of the Cepheid variable stars used to determine the distances to some of the nearer galaxies. It varies regularly from magnitude 3.6 to 4.3 in 5.37 days.

Hugging the southern horizon, the constellations Sagittarius and Scorpius lie in the thickest part of the Milky Way. Antares is a supergiant star whose name means "rival of Mars" and derives from its similar color and brightness. Mars will pass north of Antares in September, providing us with a chance to see how similar the two appear.

The all-sky map shows how the sky looks at
2:00 a.m. on June 1
midnight on July 1
10:00 p.m. on August 1


PERSEUS
ANDROMEDA
M31
CASSIOPEIA
CEPHEUS
Polaris
URSA MINOR
URSA MAJOR
DRACO
Mizar
M51
LEO
Denebola
PEGASUS
Enif
DELPHINUS
Deneb
CYGNUS
Vega
LYRA
Albireo
M13
HERCULES
CORONA BOREALIS
BOOTES
COMA BERENICES
Arcturus
SAGITTA
Altair
AQUILA
SERPENS CAUDA
SERPENS CAPUT
M5
VIRGO
Spica
Ecliptic
AQUARIUS
M11
SCUTUM
M16
M17
OPHIUCHUS
LIBRA
CAPRICORNUS
M22
M20
M8
Antares
M4
SAGITTARIUS
M6
M7
SCORPIUS
LUPUS
Magnitudes
Sirius
0.0
1.0
2.0
3.0
4.0
5.0
Open cluster
Globular cluster
Diffuse nebula
Planetary nebula
Galaxy

S	M	T	W	T	F	S
				1	2	3
4	5	◐	7	8	9	10
11	○	13	14	15	16	17
18	19	◑	21	22	23	24
25	26	27	●	29	30	31

EDT

1 **11 p.m.**
The moon passes 0.4° north of Uranus

7 **11 a.m.**
The moon passes 4° south of Jupiter

8 **11 a.m.**
The moon passes 3° south of Saturn

10 **5 a.m.**
The moon passes 0.8° north of Aldebaran

13 **3 a.m.**
Venus passes 1.5° south of Regulus (evening)

14 **5 a.m.**
The moon passes 3° north of Mercury

3 p.m.
Venus is at greatest brilliancy (magnitude –4.5)

15 **5 p.m.**
The moon passes 1.1° north of Regulus

7 p.m.
The moon passes 3° north of Venus

20 **6 p.m.**
The moon passes 7° north of Mars

26 **6 a.m.**
Neptune is at opposition

noon
Mercury is in inferior conjunction

28 **4 a.m.**
The moon passes 0.6° north of Neptune

8 a.m.
Partial lunar eclipse

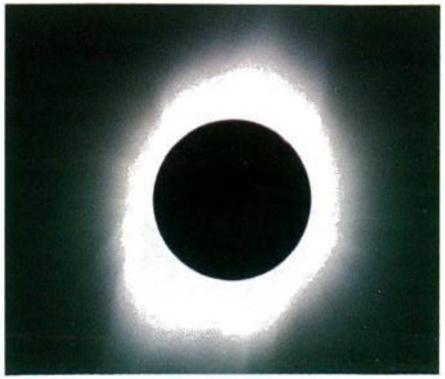
29 **3 a.m.**
The moon passes 0.5° north of Uranus

AUG

Catching the Corona One Last Time

The last total solar eclipse of the millennium occurs on August 11 (because none occurs in the year 2000). If a trip to Europe has ever appealed to you, this is the year to do it. Combine a summer tour through the spectacular historical riches of Europe with the grandest sight in all of nature — a total eclipse of the sun.

Like a fine-leaded pencil drawing a thin line across Earth's surface, the moon's shadow tracks across the Atlantic Ocean, making its first landfall in Cornwall at the southwestern tip of England. Not since June 1927, have Britons experienced a total solar eclipse on their soil. After crossing the English Channel, the central path of the eclipse passes though France, Belgium, Germany, Austria, Hungary, Romania, and Bulgaria. It is in Romania that totality lasts longest, a respectable 2 minutes and 23 seconds. The path then rushes across the Black Sea and into Turkey, northern Iraq, Iran, and Pakistan. Finally the shadow of the moon scoots off the surface of Earth just east of India, where the eclipse becomes total as the sun sets.



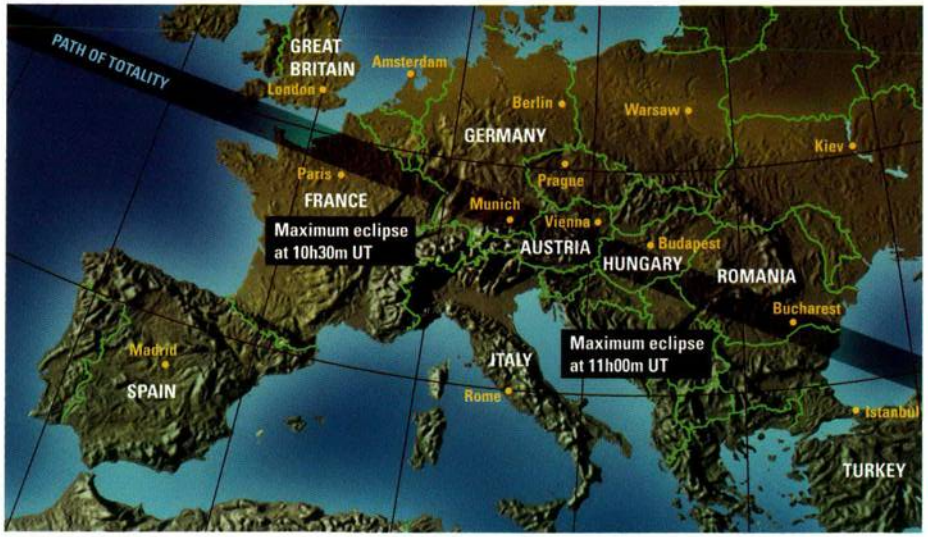
Dan Folz

Potentially, more people may see this eclipse than the major eclipse that crossed Hawaii and Mexico in 1991. This time the moon's shadow passes through the most densely populated continent on the planet and envelops many major cities, including Stuttgart and Munich in Germany and Bucharest in Romania.

The chance of good weather improves the farther east along the track you venture. Turkey has a higher percentage of clear skies in August than anywhere in Europe. Capitalizing on this, many ships plan to cruise the Black Sea during totality. The city of Istanbul lies just outside the track of totality and will be a major center of operations for many eclipse tours.

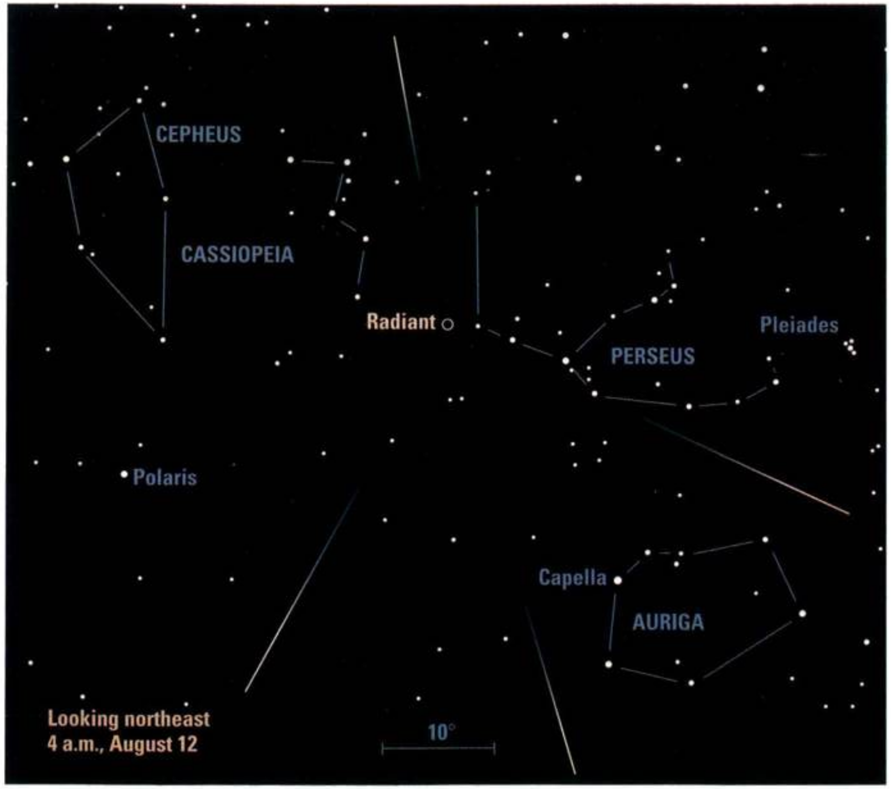
Viewing the spectacular and delicate corona is the principal reason so many people are willing to trek halfway around the world to see a total eclipse. The corona is the outer atmosphere of the sun, a tenuous gas where temperatures reach above a million degrees. The corona lies above the 10,000-degree chromosphere and the 6,000-degree photosphere, the visible face of the sun. How the corona becomes so hot was a mystery that lasted until recently. Now the combined work of years of eclipse expeditions and observations from space observatories is bearing fruit. A vast magnetic carpet that replenishes itself through energetic magnetic reconnection events seems to be the powering mechanism for heating the corona. This knowledge only adds to the overpowering beauty of a total solar eclipse.

The sun's wispy corona surrounds the moon during totality.



Catch a Falling Perseid

Conditions could hardly be better for what are traditionally the two best meteor showers of the year: August's Perseids and December's Geminids. (Although this year should offer an even better display from the Leonids in November.) With the Perseids peaking just one day after new moon, the sky will be dark and provide a spectacular backdrop for the meteor shower.

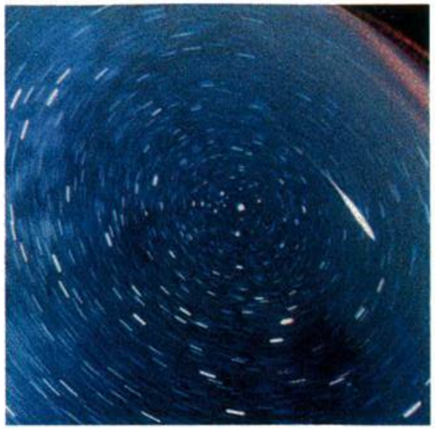


Looking northeast
4 a.m., August 12

At the peak of the shower on the night of August 12/13, you can expect to see approximately 50 or 60 meteors per hour. The numbers fall off as you get further away from the peak, but you should still see a good display from about August 10 to 15.

Perseid meteors originate as dusty debris spewed out by Comet Swift-Tuttle during its untold number of trips around the sun. Each year in mid-August, Earth runs smack into this stream of cosmic debris and our atmosphere incinerates the tiny particles, producing the flashes of light in the sky we call meteors, or "shooting stars."

Unlike Comet Tempel-Tuttle, the progenitor of the Leonid meteor shower that returned to the inner solar system in February 1998, Swift-Tuttle hasn't entered the sun's inner realm since 1992. While the swarm of debris given off by Tempel-Tuttle remains fairly concentrated near the comet, giving rise to the burst of activity we expect to see come November, the debris given off by Swift-Tuttle has spread out pretty evenly around its orbit. That's why the Perseid meteor shower gives a consistent show year after year.


Vic Winter

A Perseid meteor fireball flashes to brilliance in this wide-angle view of the August night sky.

To enjoy the Perseids to the fullest, watch after midnight – that's when Earth faces into the debris swarm and sweeps up more of the tiny dust particles. Also choose an observing site far removed from the lights of the city that offers a clear view of most of the sky. Bring along a sleeping bag or blanket to stay warm, some hot coffee or tea to stay energized, and some bug spray to stay sane. And keep a pair of binoculars handy to examine the smoke trails that many of the brighter Perseid meteors leave behind.

S	M	T	W	T	F	S
1	2	3	◐	5	6	7
8	9	10	○	12	13	14
15	16	17	◑	19	20	21
22	23	24	25	●	27	28
29	30	31				

EDT

3 **10 p.m.**
The moon passes 4° south of Jupiter

4 **8 p.m.**
The moon passes 3° south of Saturn

6 **noon**
The moon passes 0.8° north of Aldebaran

7 **3 p.m.**
Uranus is at opposition

9 **11 p.m.**
The moon passes 1.2° north of Mercury

10 **noon**
Venus passes 8° south of Regulus (evening)

11 **7 a.m.**
Total solar eclipse (visible in Europe and Asia)

12 Perseid meteor shower peaks

14 **10 a.m.**
Mercury is at greatest western elongation (19°, morning)

18 **8 a.m.**
The moon passes 7° north of Mars

20 **8 a.m.**
Venus is in inferior conjunction

24 **10 a.m.**
The moon passes 0.7° north of Neptune

25 **9 a.m.**
The moon passes 0.6° north of Uranus

26 **8 a.m.**
Mercury passes 10° north of Venus (morning)

31 **5 a.m.**
The moon passes 4° south of Jupiter

SEP

Solar Activity Begins to Heat Up

The sun is beginning to grow more active – with more sunspots, flares, and other signs of activity – as we approach another solar maximum. The most obvious type of feature you can expect to see as activity increases are the sunspots, many of which will dot the sun's surface every day. Following these magnetic marvels as they track across the sun's disk has a distinct advantage over nighttime observing: It's usually quite a bit warmer. So don a T-shirt and get ready to do some solar observing.

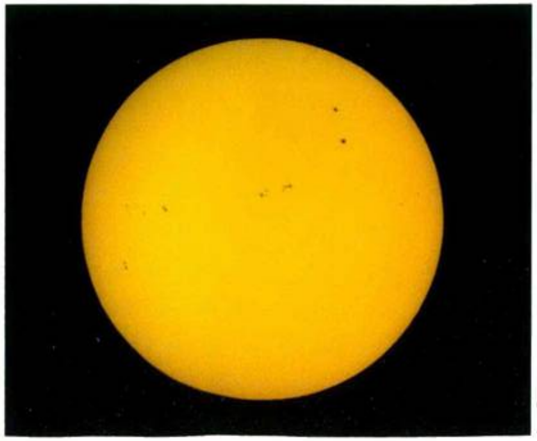
Of course, observing the sun with a telescope is fraught with danger — you must avoid looking at the sun directly without a safe solar filter or risk permanent eye damage. The only truly safe solar filters are aluminized mylar or metal-on-glass filters that fit over the front end of the telescope.

An alternative and equally safe way to view the sun is to project the sun's image onto a piece of white cardboard. This is a great way to observe sunspots and, if you draw a 6-inch-diameter circle on the cardboard, perfect for recording what you see. Plot the positions of the sunspots each day, and pretty soon you'll have a visual record that shows the rotation period of the sun.

It's likely that some major sunspot complexes will appear this year, and you can see them change shape quite noticeably from one day to the next. Also keep an eye out for the more elusive faculae, brightenings in the solar surface that tend to be associated with sunspots. By the way, sunspots appear darker than their surroundings simply because they are a few thousand degrees cooler and thus emit less radiation.

The maximum in the 11-year solar cycle is predicted to occur sometime in the year 2000. In addition to the noticeable effects it has on the sun, solar activity also affects Earth. The most obvious and beautiful of these effects are the aurorae, or the northern (and southern) lights. These curtains of light result when energetic charged particles ejected by the sun strike atoms and molecules in our atmosphere. The collisions excite the atoms and molecules, causing them to glow like the gas in a fluorescent light.

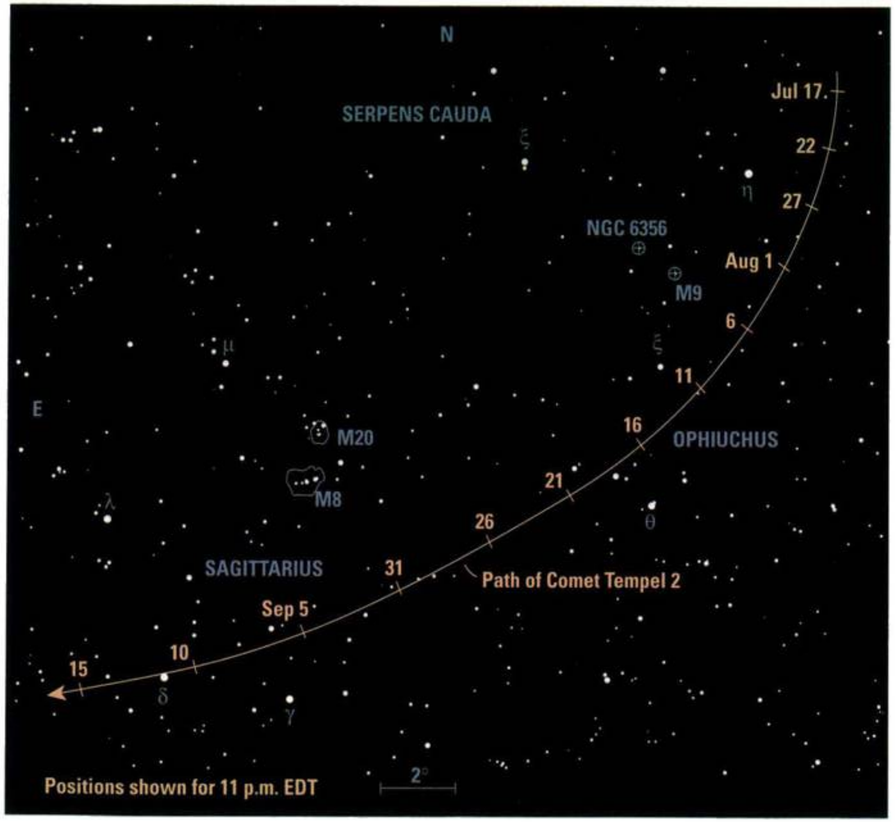
Peter Fischl


Jean Dragesco

ABOVE: The beautiful northern lights shimmer above the landscape of central British Columbia. Such aurorae, which normally favor high latitudes, should be on the increase during the next year or two. **LEFT:** The ultimate cause of aurorae are energetic particles from the sun, which is nearing the peak of its 11-year activity cycle. Cool, dark sunspots are the most obvious sign of this activity, and you can track their number quite easily with a small backyard telescope.

The Return of Comet Tempel 2

Comet Tempel 2 returns to our skies this month and should reach 9th magnitude or brighter. Tempel 2 was one of the first periodic comets to be discovered and has a period of 5.5 years. It was the second independent discovery for the German-born astronomer Wilhelm Ernst Tempel, who spotted the dim comet in July 1873 as it was making its way through Cetus.



Positions shown for 11 p.m. EDT

The comet reaches perihelion on September 8, when it lies 138 million miles from the sun, but it comes closest to Earth in mid-July at a distance of 61 million miles. The best recorded apparition occurred back in 1925, when the comet approached to almost half that distance and shone at magnitude 6.5. This year it is expected to reach peak brightness in mid-August at around magnitude 8.7.

The comet rises above 10th magnitude during the third week of June, when it can be found as a small patch of hazy light in eastern Ophiuchus. From there it heads slowly south, and on July 25 it passes 2° due west of the 2.4-magnitude star Eta (η) Ophiuchi and should be as bright as magnitude 9.0.

On its sojourn through southeastern Ophiuchus, it passes fairly near two 8th-magnitude globular clusters – M9 and NGC 6356 – that could easily be mistaken for the comet. Use the finder chart at left to tell which fuzzy object is actually Tempel 2. Another technique for differentiating the comet from the globular clusters is to carefully observe the field one night and then return to the same field a night later. The object that has moved is the comet.

PERIODIC COMETS IN 1999

Name	Perihelion date
Tsuchinshan 2	March 7
Singer-Brewster	April 6
Bowell-Skiff	April 27
Giclas	August 24
Tempel 2	September 8
Kearns-Kwee	September 16
Machholz 2	December 8
Schuster	December 16
Wild 1	December 27

Although the comet is fading by the time of perihelion, it's still worth keeping an eye on it. Tempel 2 has been known to show brightness bursts of up to a couple of magnitudes during the week or so after perihelion, as last happened in 1967. The comet can be easily found on September 12 when it passes through the same low-power field as 2.7-magnitude Delta (δ) Sagittarii.

S	M	T	W	T	F	S
			1	◐	3	4
5	6	7	8	○	10	11
12	13	14	15	16	◑	18
19	20	21	22	23	24	●
26	27	28	29	30		

EDT

1 **2 a.m.**
The moon passes 3° south of Saturn

2 **6 p.m.**
The moon passes 0.8° north of Aldebaran

7 **noon**
The moon passes 8° north of Venus

8 **11 a.m.**
Mercury is in superior conjunction
11 a.m.
The moon passes 1.1° north of Regulus

16 **6 a.m.**
The moon passes 7° north of Mars

17 **3 a.m.**
Mars passes 3° north of Antares (evening)

20 **6 p.m.**
The moon passes 0.7° north of Neptune

21 **4 p.m.**
The moon passes 0.6° north of Uranus

23 **8 a.m.**
Equinox (northern autumn /southern spring begins)

26 **11 a.m.**
Venus is at greatest brilliancy (magnitude –4.6)

27 **9 a.m.**
The moon passes 4° south of Jupiter

28 **8 a.m.**
The moon passes 3° south of Saturn

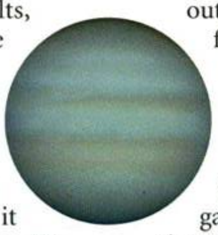
29 **midnight**
The moon passes 1.0° north of Aldebaran

30 **noon**
Mercury passes 1.7° north of Spica (evening)

OCT

The Best Jupiter Has to Offer

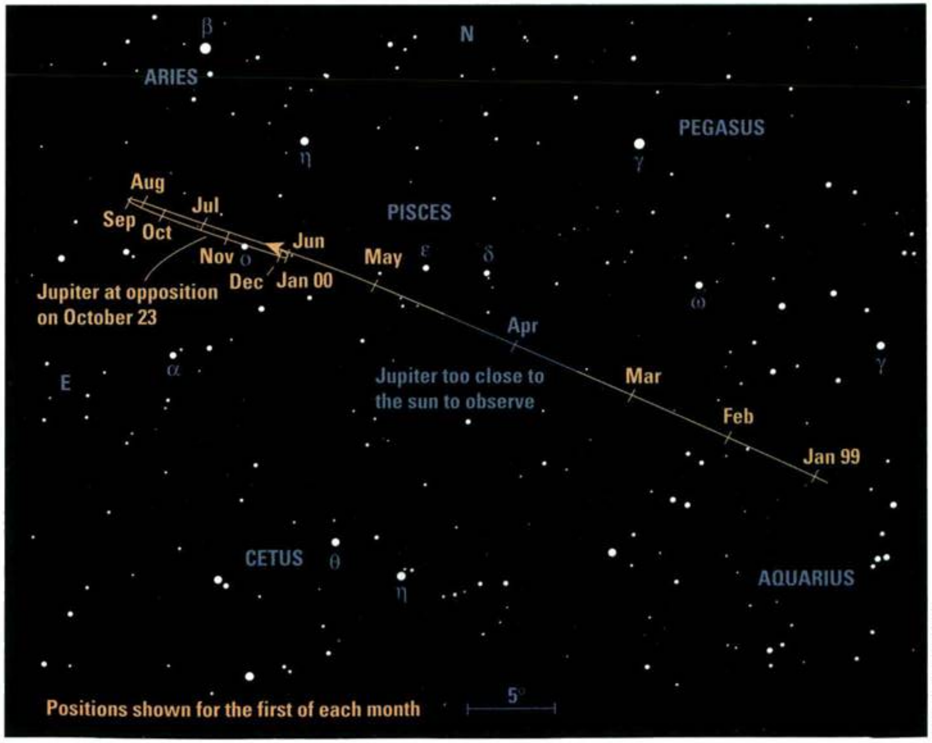
Jupiter brings many superlatives to mind. And this year brings more than usual, as it has its best opposition in 12 years thanks to the fact that Jupiter is also near perihelion. Because Jupiter orbits the sun once every 11.9 years, that's also the interval between jovian perihelions. It occurs in May this year, and opposition takes place just five months later. Jupiter reaches a staggering 50" across, making its wispy atmosphere full of belts, zones, and festoons even more visible to Earth-bound viewers.



Not only does Jupiter's proximity to Earth present wonders for telescopic observers, but the planet also rotates fast. Although 11 times the diameter of Earth, it spins once in a sprightly 9 hours 50 minutes. This fast rotation rate causes the equatorial regions of Jupiter to bulge, and it's quite noticeable through any telescope. Visible features in the planet's atmosphere rotate 36° of longitude an hour — so any features on the planet will move noticeably in less than 30 minutes of viewing. Near opposition, Jupiter is above the horizon for at least 11 hours. This means that in a single night you can see practically the entire planet rotate before your eyes.

Most noticeable are the planet's two equatorial belts, dark parallel stripes that stand out in almost any telescope. Check out these chameleon-like belts carefully, for it is in this region that much of the dramatic activity in the jovian atmosphere takes place. The other fascinating and active region is around the Great Red Spot, which has gained in prominence and color in the past couple of years. This giant storm three times the size of Earth has lasted more than 300 years. Swirls and plumes, dark spots, and white spots in the jovian atmosphere dance around the Red Spot like bees around a honey jar.

The forever-changing dance of the four major moons of Jupiter makes a perfect addition to this planetary playground for a night's observing. The four moons, first spotted by Galileo in his simple telescope back in 1610, have been under intense scrutiny during the last few years by the spacecraft with the same name, Galileo. For more than a year, the Galileo spacecraft has been making repeated close flybys of Europa — detecting evidence for oceans of water under its icy surface and revealing in stunning detail ridges and grooves crisscrossing the europan ice fields. You can see Europa for yourself in a small telescope using the set of predictions that *Astronomy* publishes each month. The other, almost equally fascinating moons — Io, Ganymede, and Callisto — join Europa in a daily shuffle.



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Jupiter at opposition on October 23
Jupiter too close to the sun to observe
Positions shown for the first of each month
5°

Photo by Donald Parker

Exploring the Autumn Sky

The cool nights of autumn are here to remind us that the chill of winter is not far off. Along with the cool air, the brilliant stars of the summer triangle descend in the west to be replaced with a rather bland looking region of sky. But don't let initial appearances deceive you. Hidden in the fall sky are gems equal to summertime, plus a couple of planets roam the region this year too.

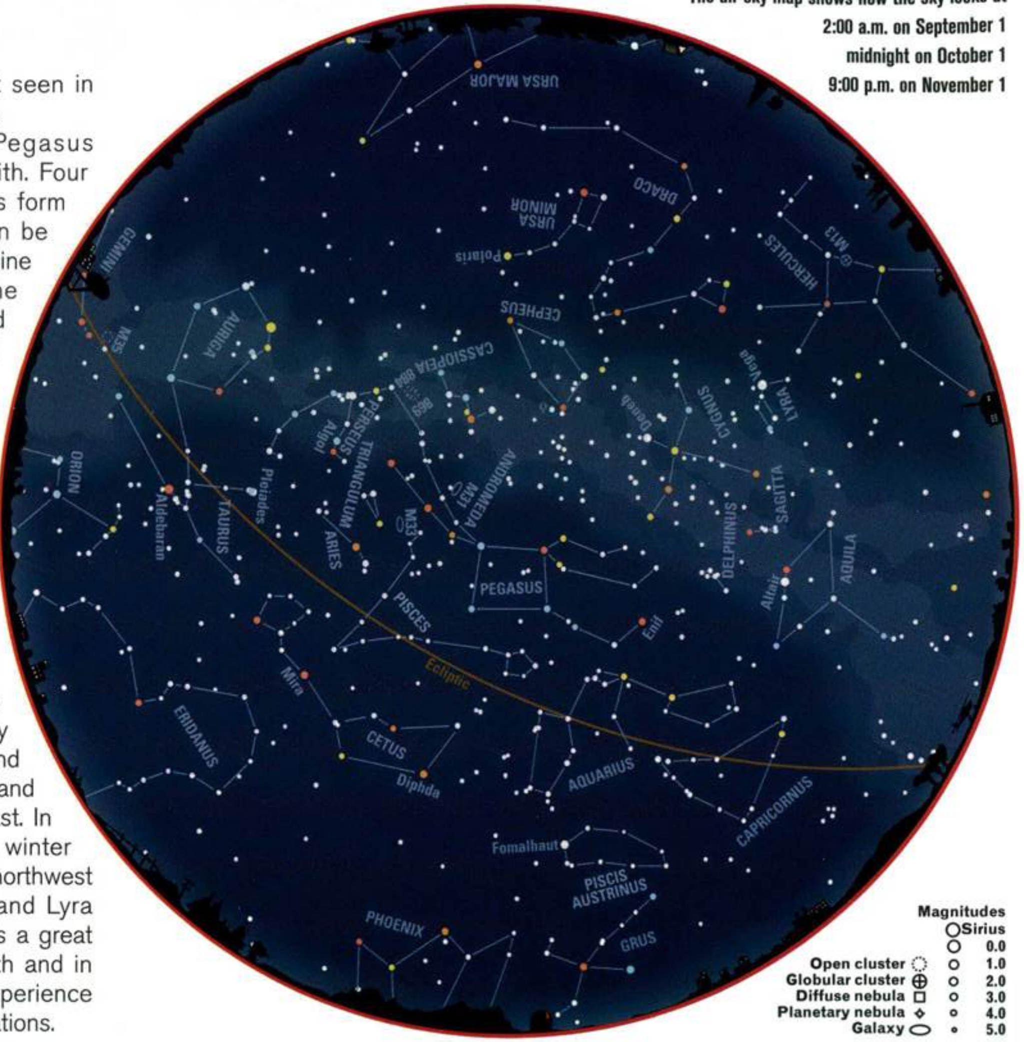
The Big Dipper swings low this season, and for parts of the southern United States it actually sets. Cassiopeia, a group of five bright stars in the form of a "W" or "M," reaches its culmination overhead, the same point the Dipper reached six months ago. To the east of Cassiopeia, Perseus rises high. Nestled between these two groups is the wonderful Double Cluster – NGCs 869 and 884 – a fantastic sight in binoculars or a low-power telescope.

Our view to the south of the Milky Way is a window out of the plane of the galaxy in the opposite direction to that visible in spring. This allows us to look at the Local Group of galaxies. Due south of Cassiopeia is the Andromeda Galaxy (M31), a 4th-magnitude smudge of light that passes directly overhead between 9 p.m. and 10 p.m. in November. Farther south between Andromeda and Triangulum lies M33, a large sprawling face-on spiral best seen in binoculars or a rich-field scope.

The Great Square of Pegasus passes just south of the zenith. Four 2nd- and 3rd-magnitude stars form the square, but few stars can be seen inside of it. If you draw a line between the two stars on the right side of the square and extend it southward, you'll find 1st-magnitude Fomalhaut in Piscis Austrinus. Fomalhaut is the solitary bright star low in the south. Using the eastern side of the square as a pointer to the south brings you to Diphda in the large, faint constellation of Cetus.

To the east of the Square lies the Pleiades Cluster (M45), which reminds us of the forthcoming winter. By late evening in October and early evening in December, Taurus and Orion are clear of the horizon and Gemini is rising in the northeast. In concert with the reappearing winter constellations, the view to the northwest finds summertime's Cygnus and Lyra about to set. The fall season is a great transition period, both on Earth and in the sky, and a fine time to experience the subtleties of these constellations.

The all-sky map shows how the sky looks at
2:00 a.m. on September 1
midnight on October 1
9:00 p.m. on November 1


URSA MAJOR
URSA MINOR
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DRACO
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M13
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CYGNUS
GEMINI
M35
AURIGA
PERSEUS
Algol
TRIANGULUM
ANDROMEDA
M31
M33
SAGITTA
DELPHINUS
Altair
AQUILA
ORION
Aldebaran
TAURUS
Pleiades
ARIES
PEGASUS
PISCES
Enif
Ecliptic
Mira
ERIDANUS
CETUS
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GRUS
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Globular cluster
Diffuse nebula
Planetary nebula
Galaxy

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●	25	26	27	28	29	30

EDT

5 **1 p.m.**
The moon passes 5° north of Venus
6 p.m.
The moon passes 1.2° north of Regulus

8 **6 p.m.**
Venus passes 3° south of Regulus (morning)

10 **11 p.m.**
The moon passes 7° north of Mercury

15 **9 a.m.**
The moon passes 5° north of Mars

18 **3 a.m.**
The moon passes 0.5° north of Neptune

19 **1 a.m.**
The moon passes 0.4° north of Uranus

21 **11 p.m.**
Vesta is in conjunction with the sun

22 Orionid meteor shower peaks

23 **3 p.m.**
Jupiter is at opposition

24 **1 p.m.**
The moon passes 4° south of Jupiter
6 p.m.
Mercury is at greatest eastern elongation (24°, evening)

25 **2 p.m.**
The moon passes 2° south of Saturn

27 **8 a.m.**
The moon passes 1.2° north of Aldebaran

30 **8 p.m.**
Venus is at greatest western elongation (46°, morning)

NOV

A Meteor Storm for the Ages

"One of the 100 most memorable events in U.S. history" was how historian R. M. Devens described the Leonid meteor storm of 1833. Bostonians described it as approaching that of a snowstorm in appearance. "A tempest of falling stars," wrote Agnes Clarke, a 19th-century popularizer of astronomy.

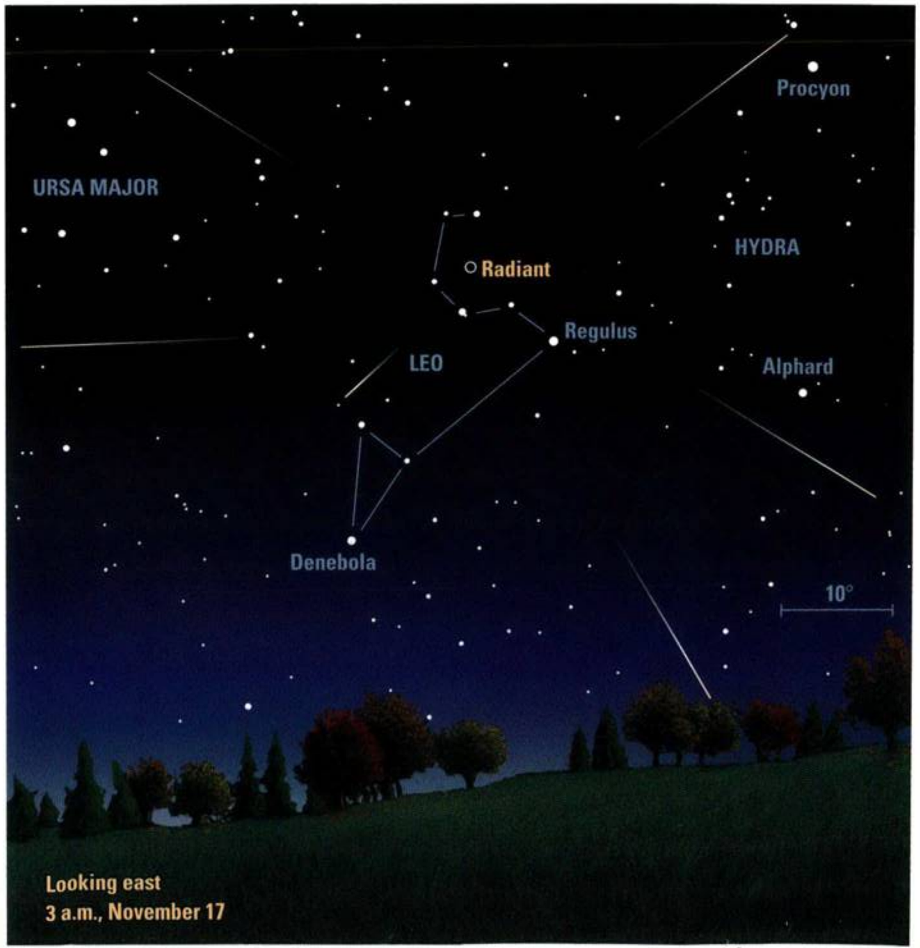
The Leonids are the most enigmatic of all meteor showers. Every 33 years or so they produce a storm of such magnitude that counting their number is practically impossible. For a brief interval up to an hour long, meteor rates have been reported as high as 100,000 to 500,000 meteors per hour. The Leonids derive from the periodic comet Tempel-Tuttle, which returned to perihelion in February 1998. The return of the comet prompted astronomers to predict more activity in the 1997–2000 period, with perhaps a storm in 1998, 1999, or both. The storms are so brief, however, that only observers in limited regions can see them.

A storm occurs when Earth passes through the richest part of the debris left by Tempel-Tuttle, a stream only a few thousand miles across. The radiant must be above the horizon at the time that Earth passes through the densest part of the stream in order for observers to see it.

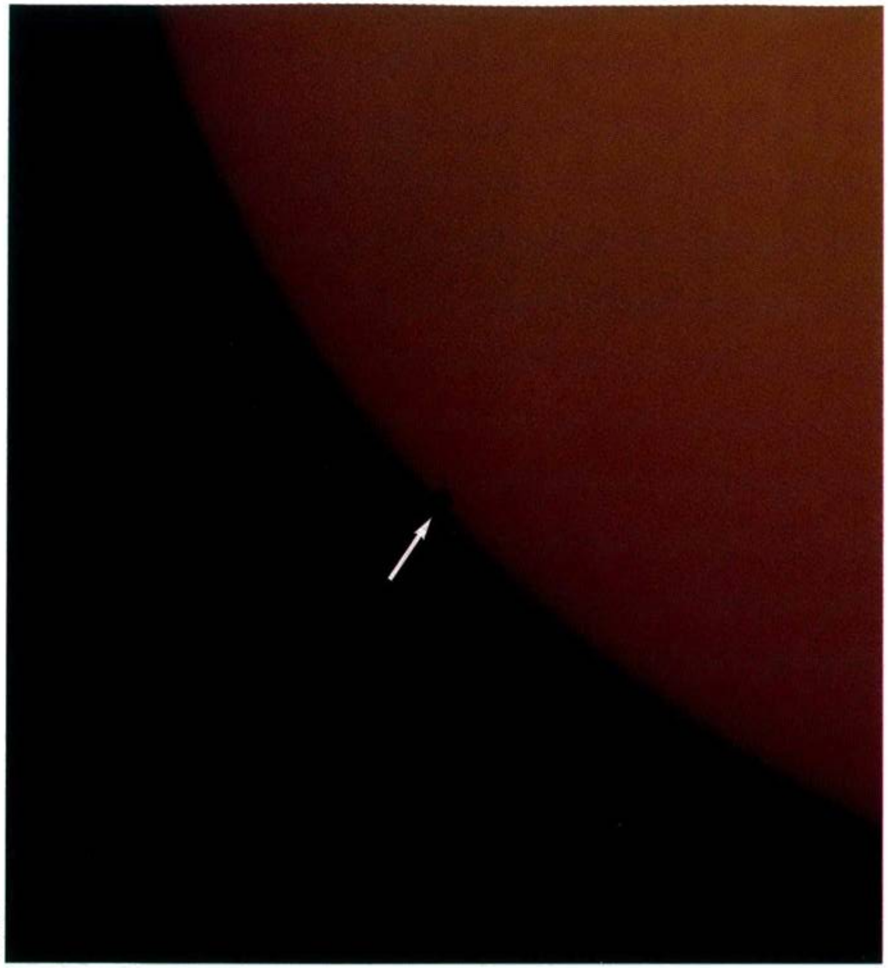
Predicting what the Leonids will be like is like trying to predict the number of snowflakes in a storm. But one thing is sure: If you don't watch before dawn on November 17 and 18, you *may* miss the show of the century.

METEOR SHOWERS FOR 1999

Name	Peak date	Moon's phase	Prospects
Quadrantids	January 4	Full	Poor
Lyrids	April 22	First quarter	Good
Eta Aquarids	May 5	Waning gibbous	Poor
Perseids	August 12	New	Excellent
Orionids	October 22	Full	Poor
Leonids	November 17	Waxing gibbous	Good
Geminids	December 14	Waxing crescent	Good



A Rare Transit of Mercury


Ernie Piini

The dark disk of Mercury edges just inside the sun's limb during its previous transit in November 1993.

An event nearly as uncommon as a meteor storm takes place during the daylight hours of November 15. The innermost planet, Mercury, passes directly between the sun and Earth, transiting the disk of our star for the first time in six years. This is the first transit of Mercury since November 1993 and the first visible from much of North America since November 1973. All of North America except for eastern Canada can witness the event, along with people in most of South America, on islands in the Pacific Ocean, and in Australia, New Zealand, and Japan.

This is a grazing transit, which means that Mercury will pass just inside the limb of the sun. (From southern Australia and New Zealand, in fact, the planet won't actually pass completely inside the sun's limb.) It will appear as a slowly moving, small black dot silhouetted against the sun's surface. Make sure to differentiate the disk of Mercury, which looks completely black, from any sunspots, which are generally larger, have more complex shapes, and are not as dark.

The transit gets under way at 4:15 p.m. EST on the afternoon of the 15th (3:15 p.m. CST, 2:15 p.m. MST, and 1:15 p.m. PST) when the limb of Mercury first touches the sun's limb. "Midtransit," when the inner planet appears farthest from the sun's limb, occurs at 4:41 p.m. EST, and Mercury finally exits the sun's disk at 5:07 p.m. EST. When Mercury passes close to the center of the sun's disk, as it did during the 1973 transit, the event takes more than five hours to unfold. This year observers will have to be content with a quick, 52-minute transit.

Because Mercury appears only 10" across during the transit, you will need at least a 2-inch telescope to spot the planet's disk. But therein lies a major danger: Without proper precautions, the sun can blind a person in just a fraction of a second. It's far better to miss the first transit visible from North America in 26 years than to have it be your last clear view of anything.

To protect your eyes, either chose a good, over-the-aperture solar filter, which blocks most of the sun's light before it enters the telescope, or project the sun's image formed by the telescope onto a white screen placed a few feet from the eyepiece. (If you use a larger scope, it helps to stop down the aperture to three or four inches to compensate for the sun's brightness.)

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14	15	◑	17	18	19	20
21	22	●	24	25	26	27
28	◐	30				

EST

3 **6 p.m.**
The moon passes 3° north of Venus

6 **9 a.m.**
Saturn is at opposition

13 **11 a.m.**
The moon passes 3° north of Mars

14 **10 a.m.**
The moon passes 0.2° north of Neptune

15 **8 a.m.**
The moon passes 0.1° north of Uranus
5 p.m.
Mercury is in inferior conjunction, transits the sun

17 Leonid meteor shower peaks

20 **5 p.m.**
The moon passes 4° south of Jupiter

21 **8 p.m.**
The moon passes 3° south of Saturn

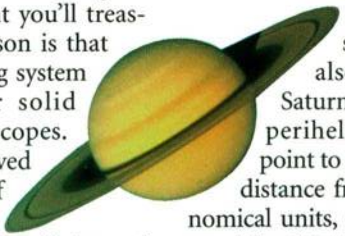
23 **5 p.m.**
The moon passes 1.3° north of Aldebaran

28 **9 a.m.**
Mars passes 1.7° south of Neptune (evening)
11 p.m.
Venus passes 4° north of Spica (morning)

DEC

Saturn's Grand Appearance

Swing into the holiday season with an evening view of Saturn. Having reached opposition on November 6, Saturn is perfectly placed in the evening sky for those late year star parties. Saturn nestles in southern Aries, a region devoid of bright stars. To its east lie the seven bright stars of M45, the Pleiades. To its west is Jupiter, the giant of the solar system.



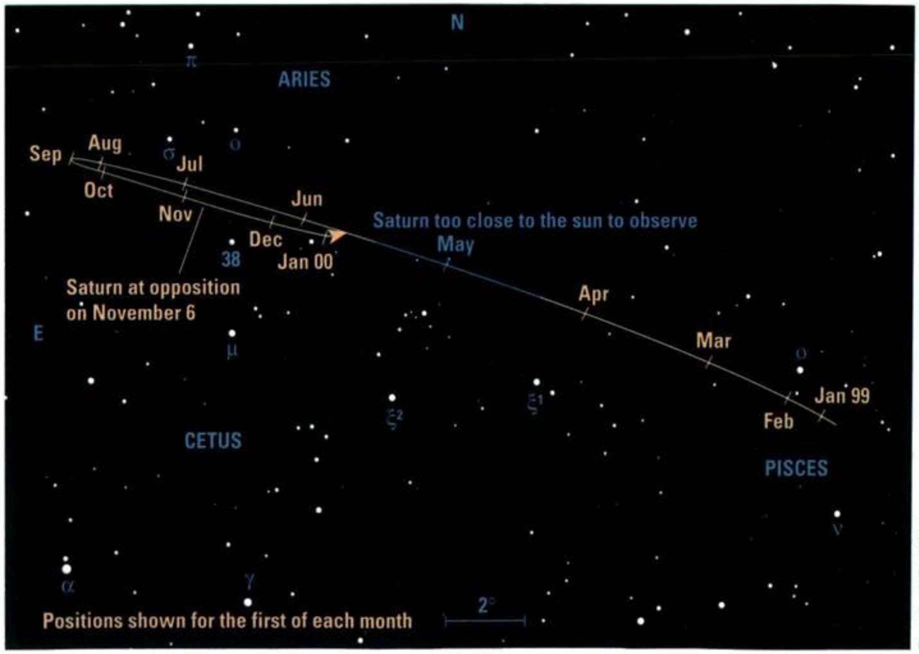
Your first sight of Saturn through a telescope will be a moment you'll treasure for a lifetime. The reason is that Saturn possesses a stunning system of rings, which appear solid through Earth-based telescopes. This year brings an improved view of the southern face of Saturn's rings.

Prior to the spectacular flybys of Saturn by the pair of Voyager spacecraft in 1980 and 1981, which led to much of our knowledge of the ringed planet, most observers could see only two or three main rings. Voyager revealed that the rings consist of thousands of ringlets. They are made up of millions of tiny clumps of rock and ice, perhaps debris that failed to form a satellite. Material this close to Saturn lies within the so-called Roche limit, where tidal stresses would have prevented any large satellite from forming.

Voyager even showed that the well-known Cassini division, a distinct gap in the rings noticeable in small scopes on Earth, was also filled with tiny debris.

Saturn is slowly approaching its perihelion, reaching its nearest point to the sun in 2003. Its average distance from the sun is 9.56 astronomical units, or 888 million miles. This year it lies 9.2 AU away, or some 33 million miles closer. By 2003 Saturn's distance from the sun will have shrunk to 839 million miles, its closest distance since its previous perihelion in 1974.

Major features on Saturn's disk are hard to see due to its prevalent atmospheric haze. Occasionally a storm brews in the atmosphere, creating a rare sight — the most famous is the major white spot discovered in 1933 by the British amateur and famous comedian of the era, Will T. Hay. The Hubble Space Telescope beautifully photographed another major storm in 1994. Most of these storms are short-lived, so keep a frequent eye on the disk of Saturn.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Saturn too close to the sun to observe
Saturn at opposition on November 6
Positions shown for the first of each month
2°

Photo by NASA/STScI

Most telescopes can discern Titan, the largest of the saturnian moons, shining at magnitude 8.3 at opposition. Other moons are fainter, but at least five are detectable in an 8-inch telescope. Perhaps the most intriguing of all is Iapetus, which is much brighter at western elongation than at eastern elongation. Voyager revealed that half of the satellite is covered in material darker than asphalt while the other half reflects light better than freshly fallen snow. You can see for yourself during this fine apparition of Saturn.

Catch the Geminids while You Can

Tim Printy

A Geminid meteor streaks across a December sky, a bit of cosmic debris meeting its demise in Earth's atmosphere.

Although it is often considered a poor cousin to the August Perseids, the Geminid meteor shower of December usually puts on a better show. (Of course, that doesn't take into account that in most of the Northern Hemisphere the weather in December is far cloudier – and colder – than in balmy August.) Still, the Geminids typically provide at least 60 meteors per hour and those rates sometimes climb close to 100 meteors per hour. The Geminids are clearly a must-see event for backyard observers, though they may pale this year in comparison to the possible storm of Leonids in November.

Conditions for this year's shower should be nearly ideal: At the shower's peak on the night of December 13/14, the moon will be in a waxing crescent phase. Its faint light won't interfere much with evening observations and will be completely gone by the prime observing hours after midnight. Geminid meteors tend to be bright, with two-thirds appearing white, one-quarter yellow, and the rest either blue, green, orange, or red.

As with any meteor shower, the best views will come if you observe from a dark-sky site. Just be sure to dress warmly (or plan to wrap yourself in a blanket or sleeping bag) and bring along a thermos of hot coffee, tea, or chocolate to ward off the chill.

The particles that form the Geminids are about the size of sand grains and smash into Earth's atmosphere at moderate speeds (at least for meteors) of about 22 miles per second. One oddity of the Geminids is that these particles don't appear to have originated in a comet. Detailed studies of the Geminid meteor stream show that it coincides with the orbit of an asteroid called 3200 Phaethon. Presumably this object was once a comet that passed through the inner solar system so many times that it lost all of its ices, leaving behind a rocky object that only appears to be an asteroid.

Unfortunately, the Geminids will not be with us forever. The stream of particles that makes the Geminid meteors is slowly drifting sideways relative to Earth's orbit. We apparently first encountered the stream in the 1700s and are now, in the last part of the 20th century, passing through the stream's dense inner part. But the drift is continuing and, if computer projections are accurate, the shower may cease within the next 100 years.

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12	13	14	◐	16	17	18
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26	27	28	◐	30	31	

EST

2 **7 p.m.**
Pluto is in conjunction with the sun
8 p.m.
Mercury is at greatest western elongation (20°, morning)

3 **4 p.m.**
The moon passes 3° north of Venus

5 **8 p.m.**
The moon passes 3° north of Mercury

11 **5 p.m.**
The moon passes 0.07° north of Neptune

12 **2 p.m.**
The moon passes 0.6° north of Mars
4 p.m.
The moon passes 0.2° north of Uranus

13 **midnight**
Mars passes 0.7° south of Uranus (evening)

14 Geminid meteor shower peaks

17 **3 a.m.**
Mercury passes 5° north of Antares (morning)

18 **1 a.m.**
The moon passes 4° south of Jupiter

19 **4 a.m.**
The moon passes 3° south of Saturn

21 **4 a.m.**
The moon passes 1.3° north of Aldebaran

22 **3 a.m.**
Solstice (northern winter /southern summer begins)

28 **3 p.m.**
Juno is in conjunction with the sun

The Bare Necessities

A novice's guide to the fundamental equipment of stargazing.

by Jeanette Brown

WHAT HOBBY DOESN'T COME WITH A LONG LIST OF essential accouterments? Cooking, for instance, is a decidedly more enjoyable pastime with an apron, a good set of knives, and a powerful food processor. And if you've set your sights on rock climbing, plan on plunking down some cash for a harness, a belay device, and a pair of those shoes that curl your feet up a few sizes smaller than they were ever intended to be. Just last week my next-door neighbor went out to purchase the essentials for his wife, a fledgling golfer: a set of clubs and a stunning turquoise golf bag on rollers — with fuzzy embossed head covers and a chic Panama hat to match (something about getting himself out of the dog house). Getting into the hobby of astronomy has a list of its own, but happily it's relatively short and sweet.

A list of the absolute essentials need include only three things, two of which you probably already have or simply cannot buy: warm clothes and dark, clear skies. The only other truly basic requirement is a red flashlight — which is not hard to come by. Then of course there are a few things you might choose to acquire later in the game.

If you're hoping to glimpse some of the sky's greatest treasures, it may require spending a few hours outside in the cool night air, so heed mom's advice and dress accordingly. Wear layers, gloves, a hat, a scarf, take a sleeping bag — the more comfortable you are, the longer you'll want to observe, and the longer you observe, the more likely you'll be to spot some spectacular objects.

To guarantee dark skies, you could try quitting your job, selling your house, and moving to a cloudless, remote, unpopulated area — say, the Australian outback. More reasonably, try to find a reliable weather forecaster who's promising clear skies that night, head into the countryside (or at least as far from city lights as possible), and hope there won't be cloud interference. As capricious as Mother Nature is, clear skies can sometimes be elusive. Time again to listen to some sage advice: "If at first you don't succeed, try and try again."

Last on the short list: Get a red flashlight. I learned this the hard way when I attended my first star party without one. Observers can get pretty persnickety where white light is concerned. And you'll understand why on your first night out. White light makes it impossible for your eyes to dark-adapt — which makes seeing faint objects in the sky considerably more difficult. Equipped with just my contraband white flashlight, I didn't dare turn it on for fear of being shot. Instead I stumbled around in the dark and tried to follow closely when folks with red flashlights were headed in the direction I wanted to go. Eventually, some kind-hearted woman, having evidently recognized my predicament, pulled me aside discreetly. She had a page of red transparent plastic that she'd purchased at a hardware store for less than a dollar. We simply traced around the head of my flashlight, cut out a circle, fit it beneath the flashlight's glass, and violà, I was instantly in league with the most serious observers.

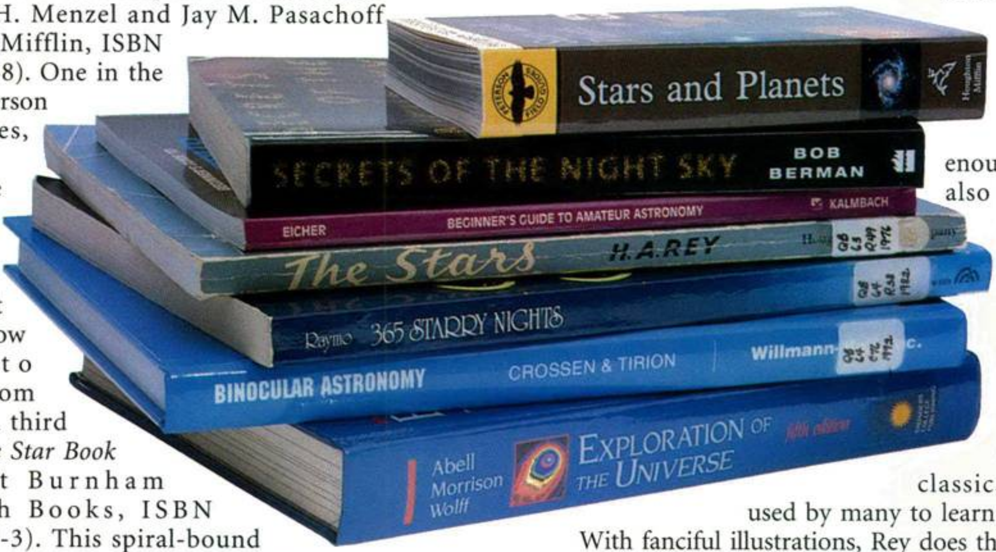
Nothing but Your Naked Eye

If you've always thought that astronomy required lots of expensive equipment, think again. In fact, naked-eye observing can be a wonderful way to ease into the hobby. With nothing more than your unaided eye and a good star atlas or planisphere, you'll quickly be able to pick out countless splendors in the night sky. Selecting a star atlas is an important step for the beginning observer, and there are a couple of categories you should consider when doing so. Atlases vary by two factors: scale and magnitude. Large-scale maps generally show only brighter stars to avoid crowding. Small-scale atlases go into greater detail and reveal fainter stars and deep-sky objects. For the purposes of a beginner, a large-scale atlas is the better choice. They cover larger tracts of the sky, which makes

Astronomy: Terri Field

recognizing and learning the constellations much easier. They also show only the brightest stars. Most large-scale maps have a limiting magnitude of 6, which is, on average, the dimmest star your unaided eye can see from a dark-sky site.

Where to start your search for a star atlas? An easy place would be in the pages of *Astronomy*. Each month the magazine has at its center a large-scale map designed to represent the sky as it will appear for Northern Hemisphere observers. Another source for star maps is *Star and Planets* by Donald H. Menzel and Jay M. Pasachoff (Houghton-Mifflin, ISBN 0-395-34835-8). One in the series of Peterson Field Guides, it's a book so invaluable in the opinion of one *Astronomy* editor that she won't allow anyone to remove it from her office. A third choice is *The Star Book* by Robert Burnham (Kalmbach Books, ISBN 0-913135-00-3). This spiral-bound atlas contains large-scale maps again emphasizing the brighter objects in the sky. The maps are complemented by text providing mythology and science about notable deep-sky objects.



You could, in lieu of a star atlas, choose instead to follow the path of planispheres. A planisphere is a two-layer disk-shaped tool that has an advantage over star atlases — it is able to show how the stars move through the sky. The top rotating layer has an opening to reveal the constellations imprinted on the layer beneath. By turning the top layer and matching the month and hour scales along the circumference, you can get a sense of the motion of the constellations in the sky during the course of an evening.

Planispheres, intended for naked-eye observing, typically display stars down to about magnitude 4 — roughly what the naked eye can see in the bright sky of a suburban backyard. There are several planispheres on the market, and they vary in quality and features. Some are made of more durable waterproof material — likely to hold up for a greater number of observing sessions. Many have white print, which is more visible in the beam of your red flashlight. Keep these characteristics in mind and select one to best suit your observing needs.

For the Bookworms

If you are the kind of person who wants a book that will tell you how to get into astronomy as a hobby, you're in luck. I took a poll of *Astronomy* staff members, and no one had trouble picking favorites. Without hesitation, these are the books our editors would recommend to folks just starting out.

An excellent resource to consult before diving into naked-eye observing is a book by Bob Berman entitled *Secrets of the Night Sky: The Most Amazing Things in the Universe You Can See with the Naked Eye* (Harper Perennial, ISBN 0-06-097687-X). In an easy-going, enthusiastic style, Berman guides the reader through the seasonal constellations.

Chet Raymo's 365 *Starry Nights* (Prentice-Hall, ISBN 0-13-920512-8) also made it onto the "A" list. Subtitled "an introduction to astronomy for every night of the year," that's exactly what this book offers. In 365 concise, illustrated essays, the book focuses on the beauty and science of the night sky. Intended for naked-eye observers, *365 Starry Nights* nonetheless includes descriptions of some things that can be observed only with the largest telescopes. In effect, the book outlines what is visible in the night sky to the unaided eye but presumes that those interested enough to look up are also interested in the science that explains what's out there but "invisible."

H. A. Rey's book *The Stars* (Houghton-Mifflin, ISBN 0-395-24830-2) is a classic, wonderful tool used by many to learn the constellations. With fanciful illustrations, Rey does the impossible — he connects the dots and helps us see the figures that constellation names refer to. The center portion of the book is a collection of useful sky charts, and the text throughout is comprehensive and information-rich — mixing science and lore into an entertaining and very useful text.

Exploration of the Universe, a textbook written by George Abell, David Morrison, and Sidney Wolff (Saunders College Publishing, ISBN 0-03-005143-6), was recommended as an excellent source for those interested in a comprehensible account of the science of astronomy. Stargazing, not surprisingly, often leads to a hunger to know more about the universe and how it works. *Exploration of the Universe* holds the answers to your science questions in language that won't mystify you.

As you graduate to binocular and telescope astronomy, *Beginner's Guide to Amateur Astronomy* should become a trusted friend. Written by David J. Eicher (Kalmbach Books, ISBN 0-913135-18-6), this book describes what every backyard observer can see in the night sky. In a lively, conversational style, it describes all types of objects visible in backyard telescopes, details what astronomers know currently about the objects in the universe, provides tips on how to find and view the best objects visible in binoculars and telescopes, and describes the many different types of telescopes, with tips on how to separate the good from the bad.

Catch the Binox Bug

So you've found a spot for star gazing and figured out how many layers of clothing it takes to keep warm — and you're probably starting to get a feel for the constellations, maybe even beginning to impress your friends by picking out the dippers, the eye of the bull, Orion's belt. What's the next step? Many would say that the time has come to invest in a pair of binoculars.

There are about as many types of binoculars as there are people who use them. We'll sweep through the basics here,

Photos by *Astronomy*: William Zuback and Jim Forbes

but if you're interested in a more complete account of how to choose the right pair for your needs, turn back to the August 1997 issue of *Astronomy* in which Stephen Edberg spells it out in depth ("Not Too Close," page 76).

For *astronomical* purposes, when choosing a pair of binoculars, the things most important to consider are optical quality, magnification, light-gathering power, and exit pupil. Cost too is likely to be a consideration. Where optical quality is concerned, the rule of thumb is that you get what you pay for. The more you can save for the pair you eventually buy, the more you'll be able to see. And remember, a good pair of binoculars should last a lifetime.

Essentially, the role of binoculars is to collect light in order to magnify a distant object and make it easier to see. Two measurements determine to what degree a pair of binoculars can do this: magnification and objective lens size. The magnification of a pair of binoculars, indicated by the first number on the binoculars' housing, tells how much closer an object will look than if no magnification were used. The size of the objective lens determines light-gathering power. For instance, a pair of 7x50 binoculars has a seven-power magnification and a 50-millimeter-diameter objective lens.

These two measurements determine a third, exit pupil. The exit pupil is perhaps the most important measurement in terms of determining which pair of binoculars is best-suited for astronomical use. It equals the objective lens divided by the magnification and is of particular importance because it tells how well your dark-adapted eye will work with a particular pair of binoculars. If the exit pupil is larger than your dilated pupil, that extra light does not enter your eye and is lost. Because an average eye's pupil opens to 7mm when fully dark-adapted, an exit pupil greater than 7 isn't useful. As a general rule for star gazing, always select binoculars with an exit pupil between 5mm and 7mm.

A wonderful complement to your newly acquired pair of binoculars is a book entitled *Binocular Astronomy* by Craig Crossen and Wil Tirion (Willmann-Bell, ISBN 0-943396-36-0). The book contains the 10-map Bright Star Atlas 2000.0, which plots most every star visible with the naked eye as well as hundreds of deep-sky objects. *Binocular Astronomy* will help you locate objects — stars, open and globular clusters, bright and dark nebulae, and galaxies — and will also explain what they are and how they fit into the universe as a whole.

Once you've graduated to binoculars, you might also want to investigate smaller-scale star atlases that show fainter stars. One good choice is Wil Tirion's *Bright Star Atlas 2000.0* (Willmann-Bell, ISBN 0-943396-27-1). The book's 10 star charts, which show stars down to 6.5 magnitude and deep-sky objects down to 10th magnitude, are enhanced by tables opposite each chart summarizing useful information. As well, half of the atlas is devoted to text aimed specifically at beginners. There are large-scale maps that show the constellation outlines and bright star names. They help you to learn the sky while guiding you to the small-scale maps that contain the dimmer stars and deep-sky objects.

Is It Telescope Time?

So you think you're ready to buy a telescope? Don't. Not until you've attended a few star parties that is. A telescope, like a car, is an investment that warrants doing some research before signing the check. Whenever my father buys a car, he reads five years' worth of Consumer Reports, visits several dealerships, and test drives as many as ten cars. At a star party, a prospective telescope purchaser can do the same — but have fun while doing it.

Star parties are events where amateur astronomers get together in a dark-sky location, set up their telescopes, often set up tents or campers to sleep in, and share the experience of observing. There are sure to be star parties planned in your region; check with local astronomy groups, science and children's museums, libraries, or even in your newspaper. (*Astronomy* also has a monthly column called "Looking Ahead," which lists upcoming star parties and events around the country.) When you've found one, take along your binoculars, but also take advantage of the many telescopes you're bound to find there. Don't be shy: Wander around the grounds and ask to look through people's telescopes. To share is why most people are there.

By attending a few star parties, you'll be able to compile your own consumer report (telescope owners are generally more than happy to talk at length about their scopes), see several different types, brands, and sizes of telescopes, and take them on a test drive. It's very difficult to get a true feel for a scope until you've put your eye to the eyepiece and had a look at the sky.

That's All Folks

As promised, the list is short. Starting out in astronomy really takes little more than patience and a love of the sky. In fact, there's really nothing stopping you from heading out tonight. Of course, if it's doodads and gizmos you seek, there's still cooking, rock climbing, or golf.

Jeanette Brown, a former editor at Astronomy, is now a graduate student at New York University.

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A Glossary of Astronomical Terms

ACCRETION DISK: a disk surrounding a black hole or star in which matter gravitationally falls onto the central object.

ALTAZIMUTH MOUNT: a mount that enables a telescope to move freely both in altitude and in azimuth.

ALTITUDE: the angle between an object's position on the celestial sphere and the horizon.

APERTURE: the diameter of a telescope's primary lens or mirror; the larger the aperture, the greater the light-gathering power.

APHELION: the point farthest from the sun in an object's orbit.

ARCMINUTE: a unit of angular size equal to 1/60 of a degree.

ARCSECOND: a unit of angular size equal to 1/3,600 of a degree (or 1/60 of an arcminute).

ASTRONOMICAL UNIT (AU): the average distance from Earth to the sun, equal to about 93,000,000 miles (150,000,000 km).

AVERTED VISION: a technique that uses the more light-sensitive rods in the eye to better see a faint object by looking at it indirectly.

AZIMUTH: the angle measured eastward from due north to the point on the horizon directly below an object.

BIG BANG: the giant explosion that created the universe 10 billion to 20 billion years ago.

BINARY STAR: a system of two stars that orbit a common center of gravity; also known as a double star.

BLACK HOLE: a region of space where gravity is so powerful that not even light can escape.

BROWN DWARF: a gaseous object that forms like a star but lacks the necessary mass to sustain nuclear fusion in its core; a body intermediate in mass between a star and planet.

CCD (charge-coupled device): a silicon chip used to detect light; CCDs are far more efficient at collecting light than conventional film.

CLOCK DRIVE: a motor attached to an equatorial mount that compensates for Earth's rotation and thus keeps the telescope pointing at the same area of sky.

CONJUNCTION: a time when two or more bodies appear close together in the sky.

COSMIC BACKGROUND RADIATION: microwave radiation that permeates the universe and represents the still-cooling glow from the hot Big Bang.

COSMIC RAY: an atomic nucleus (most are protons) moving at a speed approaching that of light.

DARK MATTER: matter that exerts gravitational force but does not emit any detectable light or radiation; dark matter comprises most of the mass of the universe but its exact nature remains unknown.

DECLINATION: the angular distance of an object above or below the celestial equator; the celestial sphere equivalent of latitude.

DEEP-SKY OBJECTS: objects located beyond the solar system; consist of stars, nebulae, star clusters, and galaxies.

DEGREE: a unit of angular size equal to 1/360 the circumference of the celestial sphere; the sun and moon both appear about half a degree wide.

DOPPLER EFFECT: the change in wavelength coming from a source that's moving toward or away from an observer; produces either a blueshift or redshift.

ECLIPSE: an event in which one body passes in front of another, blocking it partially or completely from view.
Solar: an eclipse of the sun caused by the moon passing between Earth and the sun.
Lunar: an eclipse of the moon caused by the Earth passing between the sun and moon.
Annular: a solar eclipse in which the moon does not fully cover the sun's disk, allowing observers to see a thin ring of sunlight.

ECLIPTIC: the plane of Earth's orbit around the sun; all the planets except Mercury and Pluto have orbits in nearly the same plane.

ELECTROMAGNETIC RADIATION: the various forms of light; includes radio waves, infrared light, visible light, ultraviolet light, x rays, and gamma rays.

ELONGATION: the apparent angular separation of an object from the sun.

EQUATORIAL MOUNT: a mount in which one axis lies parallel to Earth's rotational axis; the motion of the telescope about this axis can compensate for Earth's rotation.

EVENT HORIZON: the boundary of a black hole from inside which light cannot escape.

EYEPIECE: a magnifying lens used to view the image produced by a telescope's objective.

FOCAL LENGTH: the distance from a lens or mirror to the point where it brings light to a focus.

FOCAL RATIO (F/RATIO): the ratio of the focal length of a lens or mirror to its diameter.

FOCUS: the point at which rays of light passing through a lens (or reflecting off a mirror) converge.

GAMMA-RAY BURST: a short, intense burst of high-energy radiation emanating from the distant universe.

GAMMA RAYS: the form of light with the shortest wavelength and the most energy.

GAS GIANT: a large planet made primarily of gas; such as Jupiter, Saturn, Uranus, and Neptune.

GIBBOUS: the phase of the moon between first quarter and last quarter, when the moon appears more than half illuminated.

GLOBULAR CLUSTER: a roughly spherical congregation of hundreds of thousands of stars; most globular clusters consist of old stars and exist in a galaxy's halo.

GRAVITATIONAL LENSING: the distortion or amplification of an object's light due to the presence of a massive object in the light path.

HALO: the outer region of a galaxy containing globular clusters, a few stray stars, and dark matter.

HUBBLE CONSTANT: the value that expresses the expansion rate of the universe and is equal to the recessional velocity of a galaxy divided by the distance to the galaxy; usually expressed in kilometers per second per megaparsec (3.26 million light-years).

INFRARED LIGHT: a form of light with slightly lower energy than visible light but with greater energy than radio waves.

KELVIN: a unit of temperature equal to one degree on the Celsius scale and 1.8 degrees on the Fahrenheit scale; also the absolute temperature scale defined so that 0 kelvin is absolute zero.

KUIPER BELT: a region in the outer solar system beyond Neptune's orbit that contains billions of small, icy bodies; Pluto is the largest known Kuiper belt member.

LIGHT-YEAR: the distance light travels in one year; equivalent to approximately 5.9 trillion miles (9.5 trillion km).

LOCAL GROUP: the galaxy cluster containing roughly 35 galaxies to which the Milky Way Galaxy belongs.

LUMINOSITY: the total amount of light that an object radiates.

MAGNITUDE: the measurement of the brightness of an object; the lower the number, the brighter the object.
Absolute: the apparent brightness an object would have if it were 10 parsecs (32.6 light-years) from Earth.
Apparent: the measure of the brightness of an object as seen from Earth.

MASS: a measure of the total amount of matter within an object.

MERIDIAN: an imaginary circle on the celestial sphere that connects the zenith to the north (or south) celestial pole.

METEOR: a flash of light that occurs when a meteoroid burns up in Earth's atmosphere; also popularly known as a shooting star.

METEORITE: a rock from space that survives passage through Earth's atmosphere and falls to the ground.

MILKY WAY: the band of light that encircles the entire sky and results from the combined light of billions of stars in our galaxy's disk.

MILKY WAY GALAXY: the spiral galaxy to which Earth belongs.

NEBULA: a cloud of interstellar gas and dust; some nebulae represent stellar nurseries, others represent stellar graveyards.

NEUTRON STAR: the collapsed, extraordinarily dense, city-sized remnant of a high-mass star.

NOVA: a violent explosion on the surface of a white dwarf, which causes the star to temporarily brighten by a factor of several hundred to several thousand.

OBJECTIVE: a telescope's primary lens or mirror that gathers light and brings it to a focus.

OCCULTATION: the passage of one object in front of a smaller one, temporarily obscuring all or part of the background object from view.

OORT CLOUD: a cloud of cometary nuclei that surrounds the sun at a distance of many thousands of astronomical units.

OPEN CLUSTER: a system containing a few dozen to a few thousand stars that formed from the same stellar nursery.

OPPOSITION: the moment when a planet farther from the sun than Earth appears opposite the sun in the sky; it is the best time to observe a planet.

PERIHELION: the point closest to the sun in an object's orbit.

PHASE: the regular cycle of changes in the appearance of a moon or planet.

PHOTONS: individual "particles" of light.

PLANETARY NEBULA: a glowing shell of gas ejected by a dying low-mass star.

PULSAR: a rapidly rotating neutron star that bathes Earth in regular pulses of electromagnetic radiation.

QUASAR: the highly energetic core of a young galaxy thought to be powered by a supermassive black hole; short for quasi-stellar object.

RADIO WAVES: the form of light with the longest wavelength and the least energy.

RED GIANT: a cool star near the end of its life cycle that has expanded to a diameter a few dozen to a hundred times that of the sun.

REDSHIFT: an increase in the wavelength of light coming from an object due to its motion away from Earth, the expansion of the universe, or a strong gravitational field.

REFLECTOR: a telescope that uses a curved mirror to gather light.

REFRACTOR: a telescope that uses a glass lens to gather light.

RESOLUTION (or resolving power): the ability of a telescope or camera to pick out fine detail.

REVOLUTION: the orbital motion of one body around another body or a common center of mass.

RIGHT ASCENSION: the angular distance of a celestial object east of the vernal equinox; the celestial sphere equivalent of longitude.

SEEING: the quality of observing conditions induced by turbulence in Earth's atmosphere, which blurs the images of astronomical objects.

SINGULARITY: the central point of a black hole where matter is concentrated into an area of zero volume and infinite density.

SOLAR WIND: the stream of charged subatomic particles emanating from the sun.

SUPERNOVA: the cataclysmic explosion of a high-mass star.

TERMINATOR: the boundary on a planet or moon separating the illuminated side from the unilluminated.

ULTRAVIOLET RADIATION: a form of light with higher energy than visible light, but without as much energy as x rays.

UNIVERSAL TIME: the local time of day on a line of longitude centered on Greenwich, England; it forms the basis for all civil timekeeping.

VISIBLE LIGHT: the form of electromagnetic radiation that humans can see with their eyes.

WHITE DWARF: the dense, collapsed, Earth-sized remnant of an intermediate-mass star like the sun.

X RAYS: electromagnetic radiation more energetic than ultraviolet light but less energetic than gamma rays.

ZENITH: the point on the celestial sphere directly over the head of an observer.

ZODIACAL LIGHT: a faint, cone-shaped glow of light seen in the west after nightfall or in the east before dawn caused by sunlight reflecting and scattering off interplanetary dust particles lying along the ecliptic plane.

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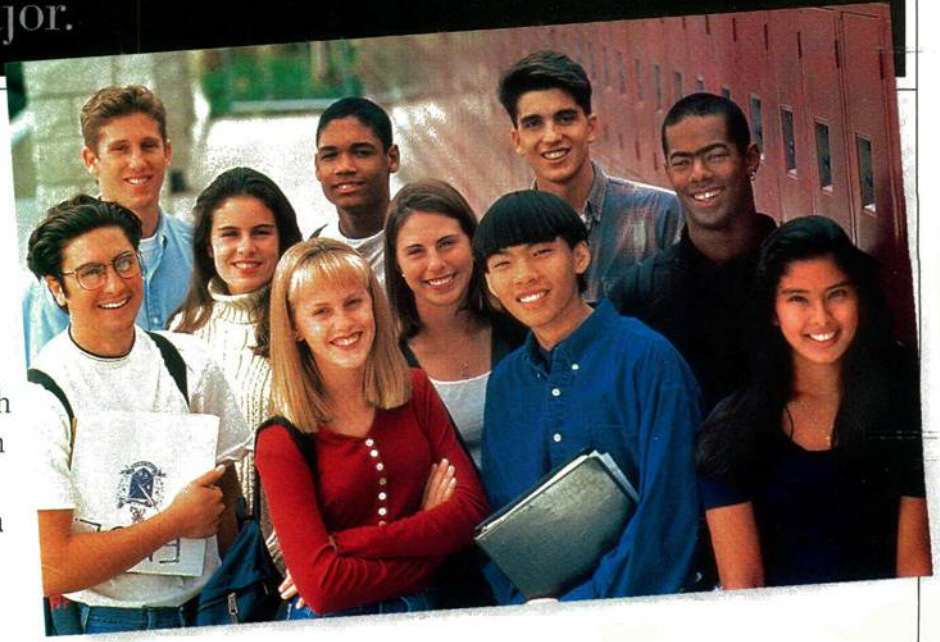

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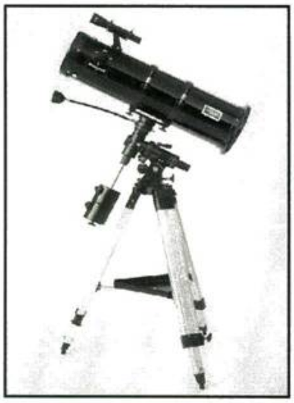

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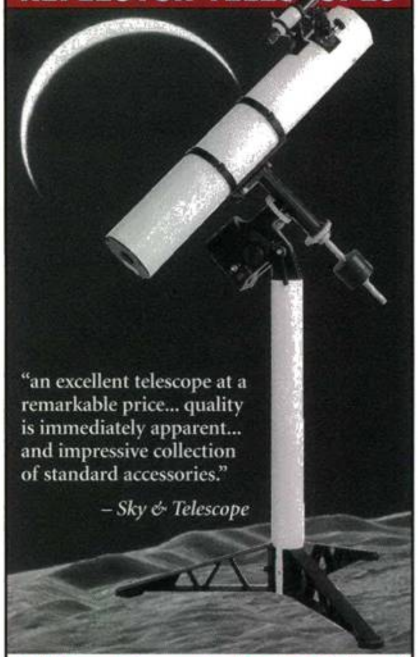

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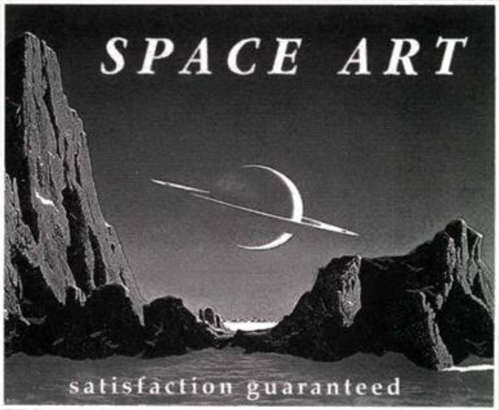

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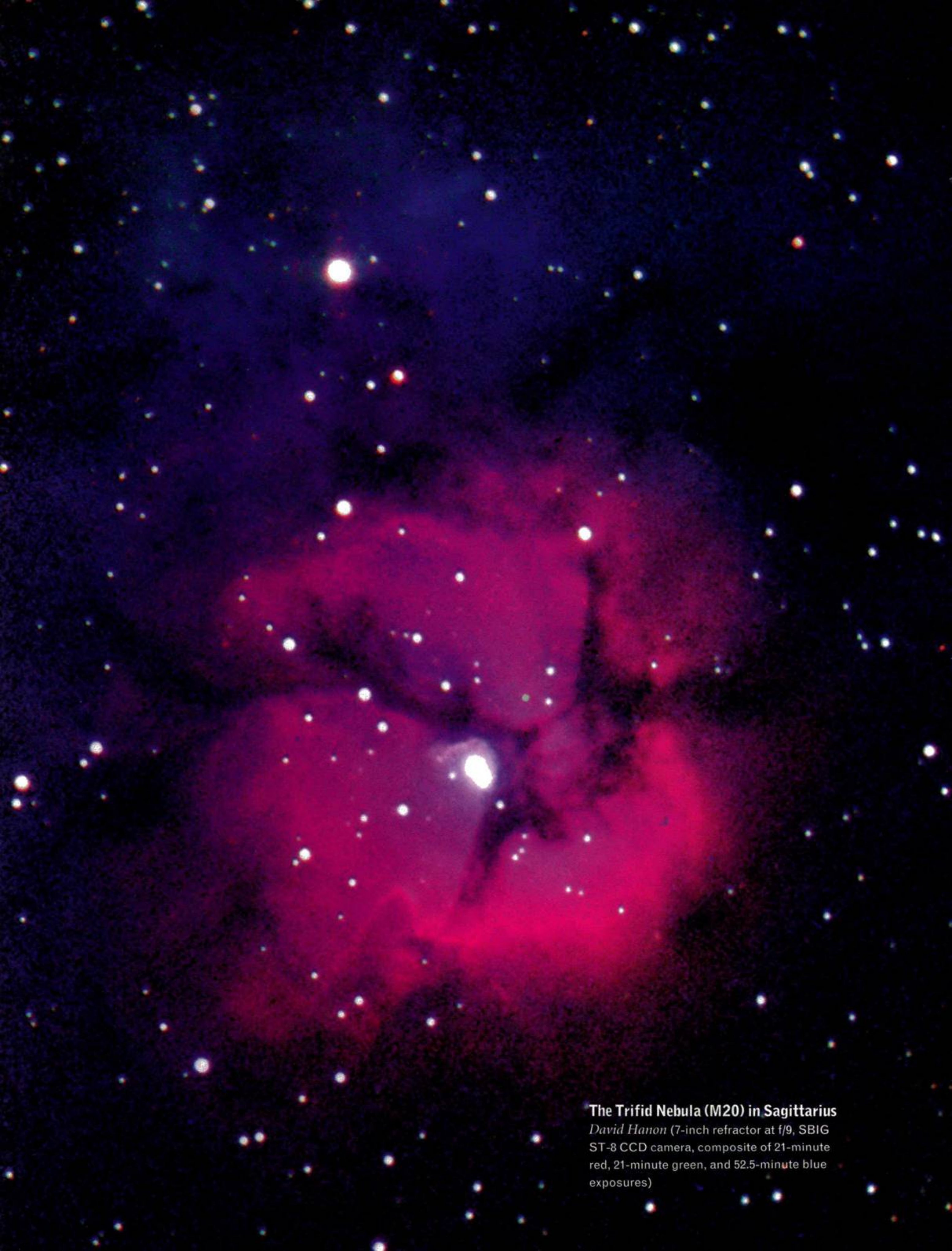


The Trifid Nebula (M20) in Sagittarius
David Hanon (7-inch refractor at f/9, SBIG ST-8 CCD camera, composite of 21-minute red, 21-minute green, and 52.5-minute blue exposures)

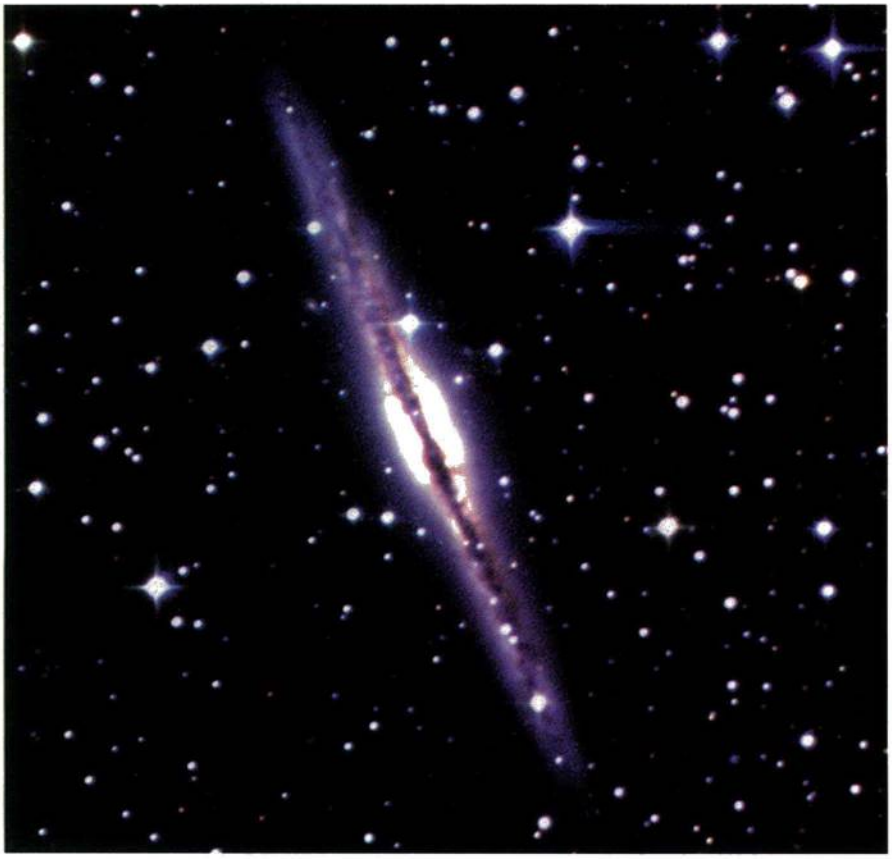
Like magic, CCD cameras are replacing shutters and darkrooms.

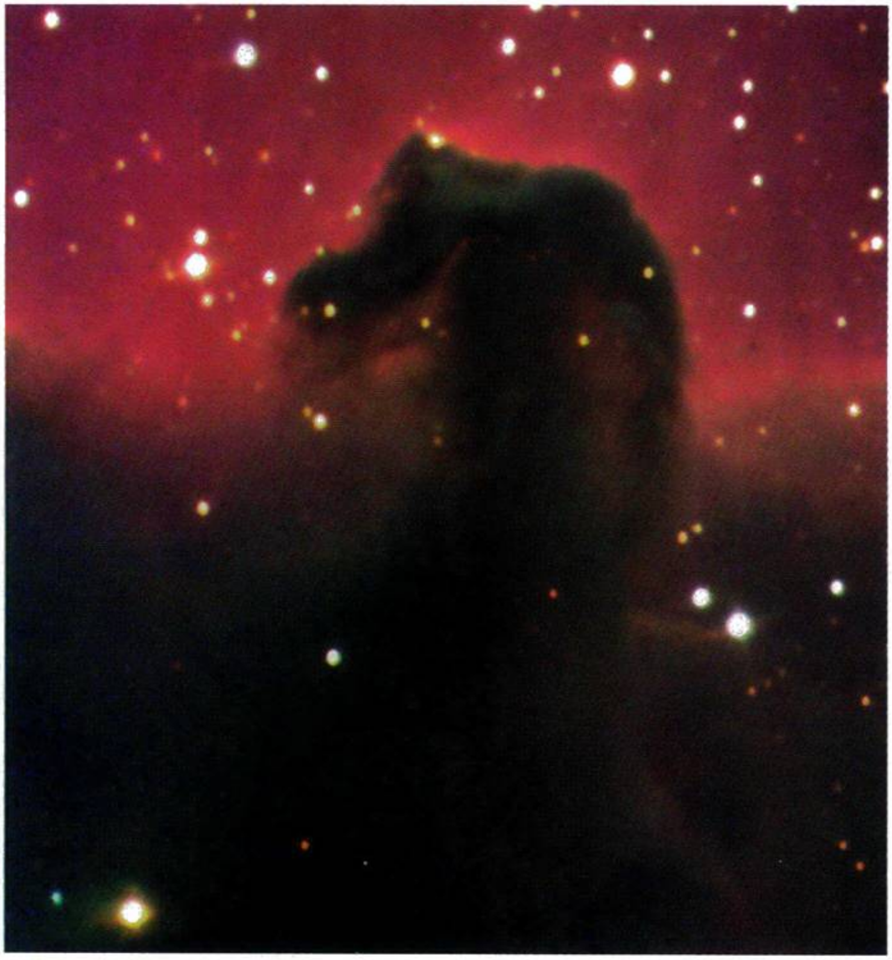
by Gregory Terrance

FROM DARKROOM TO DIGITAL

A century ago, Edward E. Barnard and other astronomers first used film plates to record deep-sky images. The photographs they produced revealed objects that had been completely invisible, even with the aid of a telescope. What seemed miraculous then has slipped into the background: For many amateur astronomers, digital imaging has replaced photography and visual astronomy as the detector of choice in nearly all professional observatories.

A digital camera contains a charged-coupled device (CCD) that is used in place of film. CCDs are now as commonplace as home computers. Millions of people use them in video camcorders, and point-and-shoot CCD cameras are popular alternatives to film-based cameras. Many amateur astronomers have also switched over to the new digital medium. The term "astro-imager" describes this new breed of astronomers that captures the sky digitally. A CCD is a silicon-based sensor, a computer chip that converts light from an optical image into an electronic signal. Film in a conventional camera records an image on silver halide grains when light strikes them, and CCD chips





record the images in a similar way with electrons. Unlike film, a CCD chip is fixed in its camera's interior and never has to be replaced. Once a photographer completes and downloads the image to a computer, the digital camera is ready to take another image. Such digital images don't require a darkroom for processing — in effect, the computer is the darkroom.

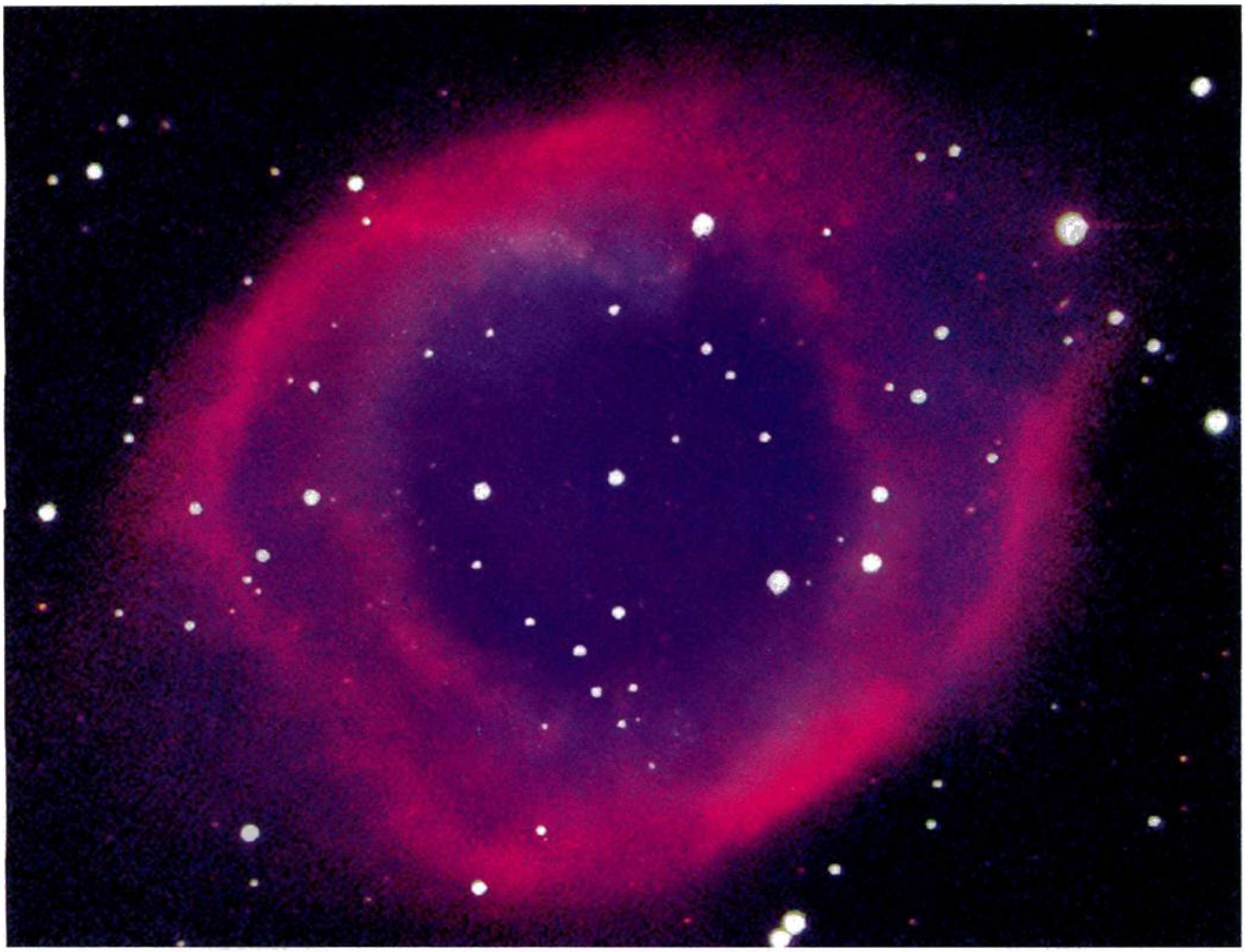
The Power of Digital Imaging

Charged-coupled devices are extremely sensitive to light, and that enables them to sense objects that are difficult or impossible to record with film. A typical CCD can detect one of every two photons of light that strikes it. Most films, on the other hand, record only one of every 50 incoming photons. This difference in efficiency allows a digital camera to record fainter objects in shorter periods than is possible with film. For instance, a CCD camera used with a 40-inch telescope can actually detect fainter objects than a 200-inch telescope equipped with photographic plates.

In addition to being super sensitive, a CCD's response to light is linear. A 20-minute exposure with a digital camera will yield twice the signal of a 10-minute exposure, and this remains true for long or short exposures. Even the best films cannot boast this ability. In fact, a film's actual "speed" changes during the course of an exposure. Long-exposure photos suffer from a dramatic decrease in a film's recording power and a corresponding reduction in its speed.

Digital imaging has other advantages over photography. A CCD responds to a wider range of light wavelengths than does film. This extended spectral response enables a digital camera to record objects that are completely invisible to astrophotography. A CCD can also record objects that have vastly different brightness levels. Because of its wide dynamic range, a digital camera can show very

Top: NGC 891 in Andromeda *Tim Puckett* (24-inch f/5 Ritchey-Chrétien reflector, Apogee AP7 CCD camera, composite of three 10-minute red, green, and blue exposures)
Bottom: The Horsehead Nebula (B33) in Orion *Jack Newton* (25-inch f/5 Newtonian, Meade Pictor 1616 XT CCD camera, composite of 5-minute red, 20-minute green, and 40-minute blue exposures)



Above: The Helix Nebula (NGC 7293) in Aquarius *Tim Puckett* (12-inch f/6.2 SCT, Apogee AP7 CCD camera, composite of three 300-second exposures through red, green, and blue filters) **Right: The Crab Nebula (M1) in Taurus** *Jack Newton* (16-inch SCT at f/6.3, Meade Pictor 1616 XT CCD camera, composite of 5-minute red, 20-minute green, and 20-minute blue exposures)

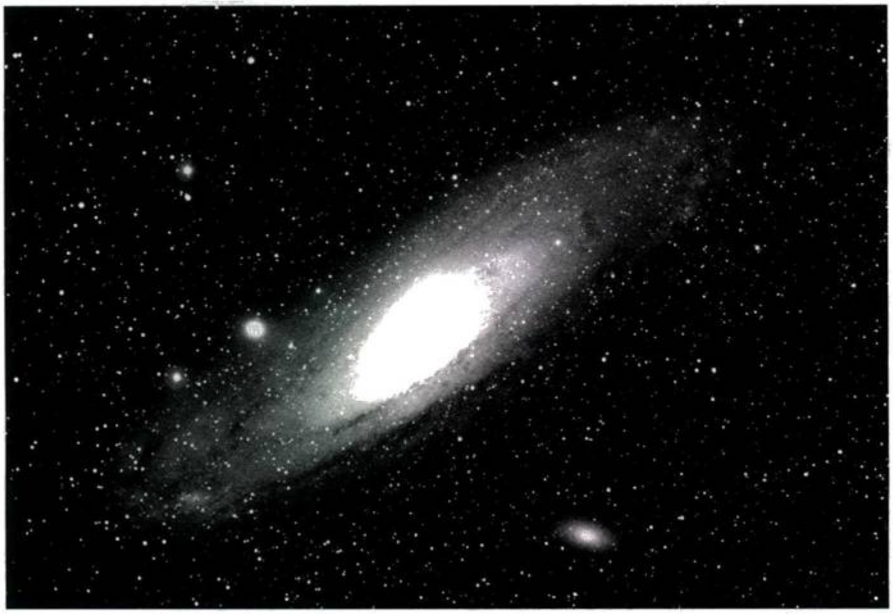
bright and very dim objects in the same field of view, in a single exposure.

As powerful as it is, digital technology has not yet advanced to the point where it surpasses photography in every respect. Due to manufacturing limitations, the largest CCD arrays are small compared with film. Film can be produced in large sheets that dwarf the chips in digital cameras. Therefore, film can capture a larger area of the sky than a CCD can when used with a given telescope. Film also has the advantage of taking single-exposure color images; CCDs, on the other hand, are monochromatic by design; they're equivalent to black-and-white film.

Producing a color CCD image requires taking three separate exposures in red, green, and blue and combining them electronically.

CCD Cameras for Astronomy

A digital camera designed for astroimaging has a fundamental difference from its point-and-shoot counterpart. The CCD detector in an astronomical camera has to be cooled, whereas the detector in a "portrait" CCD camera does not. Cooling is important for astronomical CCD cameras because all CCD detectors suffer from noise that will make an image looked "grainy" if not corrected. Noise is a result of defects in pixels across the CCD array. Cooling a CCD detector reduces the rate that noise builds up during an exposure. Point-and-shoot cameras can get away without cooling because most of the exposures are less than one second and noise doesn't have much time to generate. Since most astronomical objects usually require much longer exposures, cooling becomes important for high-quality astro-imaging. Astronomical CCD camera manufacturers and approximate price ranges include Apogee Instruments ($5,000 to $50,000), Celestron International ($1,495), Finger Lakes Instrumentation ($2,000 to $14,000), Meade Instruments ($495 to $4,995), Santa Barbara Instrument Group ($595 to $6,495), and Starlight Xpress ($975 to $2,195).



Top: M101 in Ursa Major *Kim Zussman* (14.5-inch f/8 SCT, HPC1 CCD camera, 15-minute exposure) **Bottom: The Andromeda Galaxy (M31) in Andromeda** *Gregory Terrance* (4-inch refractor at f/4.5, FLI IMG 1300 CCD camera, 30-minute exposure)

Using a CCD Camera for Astro-Imaging

If you're ready to jump into the digital fray, make sure that your telescope is in good working order. A digital camera will reveal any shortcomings that you may have in the system. While each component (mounting, focuser, optics, drive, etc.) should be examined for weaknesses, the greatest gains for the least amount of money can usually be found by improving the focuser.

Because focusing is crucial to getting good images, a focuser that lacks a locking mechanism, exhibits image shift, or is unable to accommodate fine adjustments should be replaced. In fact, many of the high-quality focusers on the market today owe their existence to the demanding nature of CCD imaging. For more information on CCD-related telescope improvements, see "Tune Up Your Telescope for CCD" (*Astronomy*, September 1995).

Deep-Sky Imaging

Successful deep-sky CCD imaging depends primarily on precise focusing and accurate tracking. As with all types of imaging, the importance of focusing cannot be overemphasized. Fortunately, a digital camera has the ability to magnify the view of a star image (zoom in) so that it can be examined as the camera is focused. The usefulness of on-the-screen focusing is limited though, and further refinements are needed for precision focusing. There are many ways to achieve critical focus; one rule of thumb is to begin with the recommendations of the camera manufacturer and develop your own system that provides consistently good results. (See "Getting Focused on Sharper Photos," *Astronomy*, July 1993.)

Tracking accuracy depends on the quality of the right ascension drive and the mount's polar alignment; you should make every effort to optimize both. To achieve low-noise images, use the longest exposure your mount can tolerate without tracking errors, and use a CCD camera with a properly cooled, low-noise chip.

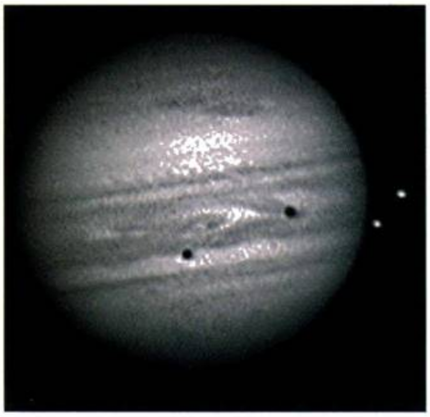
Planetary Imaging

Producing high-resolution CCD images of planets requires getting everything exactly right. Not only do you need quality optics, but they must be well collimated (aligned), held stress free, and perfectly focused. That's a tall order, but with some perseverance and attention to detail, CCD planetary images can be stunning — far exceeding film-based images taken with the same setup. The finest optics, however, will not perform well if they are not properly aligned. Be sure to check your telescope's collimation before every imaging session. The focuser should be robust enough to hold the camera without wobbling, but it should also operate smoothly enough for small, incremental changes.

Digital exposure times of the planets are short compared with film exposures, and this increases the chances of getting a great planetary image when the atmosphere is steady. Because nothing can be done about upper atmospheric conditions, control local seeing conditions by placing the telescope away from heat sources such as rooftops and parking lots. It's also important to allow the telescope's optics to cool down to ambient temperatures. Some telescopes, such as large Newtonians or refractors, can take more than an hour to reach thermal equilibrium.

Tri Color Imaging

Having conquered the basics of CCD imaging, you may want to try your hand at color imaging. Because CCDs are inherently monochromatic, color imaging is only possible by taking three images of the same object through red, green, and blue filters. Filtered images require additional equipment and much longer exposures. Consequently, tri color imaging is much more difficult and time consuming. Even so, the pages of *Astronomy* showcase many photographs that prove that amateurs feel tri-color images are well worth the trouble.



Top: Jupiter with Moons Io and Callisto *Gregory Terrance* (16-inch reflector scope at f/25, SpectraSource Lynxx CCD camera, 3-second exposure taken April 6, 1992) **Center: Rosette Nebula (NGC 2237–9) in Monoceros** *David Hanon* (7-inch refractor at f/6, SBIG ST-8 CCD camera, mosaic of six 20-minute exposures) **Bottom: The Sombrero Galaxy (M104) in Virgo** *This image is the result of combining an RGB image taken by Al Kelly with a monochrome image taken by Ed Grafton.* (8-inch SCT at f/6, CB 245 CCD camera, composite of 4-minute red, 8-minute green, and 14-minute blue exposures. Monochrome image: 14-inch f/7 SCT, SBIG ST6 CCD camera, 40-minute exposure)

Trickle-Down Technology

Digital cameras have become an essential tool at every major observatory in the world and on the Hubble Space Telescope. In recent years the digital bug has also bitten many amateurs. In many ways, we are indebted to the professional astronomers who have pushed the envelope of CCD technology — their cutting-edge technology will eventually become ours. The current crop of amateur digital cameras has improved to the point where their images surpass film-based images taken through the same telescope. Perhaps now is the right time for you to take the digital plunge and become an astro-imager. ■

Gregory Terrance's last Astronomy *article was "CCD Cameras Get Savvy," (April 1998). His website is located at http://www.frontiernet.net/~gregoryt/*

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M51 Whirlpool Galaxy. *The first galaxy found to have spiral structure is about 35 million light years distant and about 10 arc minutes in apparent diameter. This five-minute ST-5C exposure was taken in moderate light pollution with a Celestron C8 reduced to f/4 using the ST-5C focal reducer. Courtesy Alan Holmes and Michael Barber / SBIG.*

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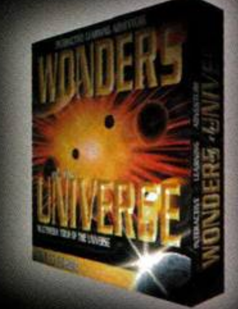

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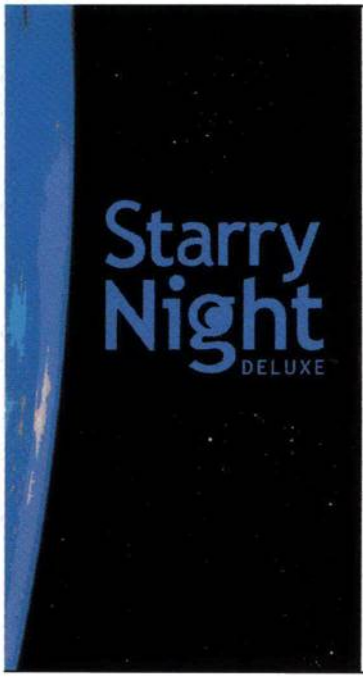

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Patti's Picks

3-D Tour of the Sola

Join *Astronomy's* webweaver as she chooses her favorite CD-ROMs of the year.

At first blush, the mission sounded simple enough – pick four of my favorite astronomical CD-ROMs released since last year's *Explore the Universe.* However, by the time I procrastinated to the last possible second of the eleventh hour, I had to admit this was one mission I would have preferred not to accept. Unfortunately, my editor was becoming a permanent fixture in my office, so I made some difficult choices. There were many great titles released last year, but some stood out.

My first pick is an international endeavor which explains its somewhat worldly flavor. *Astro 2001: The Wonders of the Universe*, is first in a series of titles being developed for the teaching and popularization of a wide array of sciences. Authors Patrick Moore, Jiri Grygar, and Zdenek Pokorny have successfully brought years of education, science writing, and astronomy into this CD-ROM devoted to astronomy.

ASTRO 2001 The Wonders of the Universe

The *Wonders of the Universe* voyages from the Big Bang to space travel, and artfully introduces the significant moments in the development of our universe. Your journey explores galaxies, black holes, star gazing, the solar system, constellations, and more. With video recordings, tests and questions, almost three hours of narration, 48 diagrams, and 392 photographs, the designers of this multimedia extravaganza have created an astronomical feast for the mind.

Its playful approach to learning might just have families fighting over the computer, because *The Wonders of the Universe* has something for everyone using Windows 95.

D-data, Inc., 1 World Trade Center, New York, NY 10048; phone (212) 524-0694; fax (212) 775-7824; website, www.astro2001.org. Price: $44.95.

My second choice revolved around one of the most important questions human beings ask – "Are we alone in the universe?" Many brilliant minds in the world search for the answer to this question, and one of the most dazzling, Stephen Hawking, has contributed to a CD-ROM that makes his lectures, theories, and exploration accessible to all audiences with point-and-click ease. In plain language, *Life in the Universe* explains cosmological concepts, black holes, physics such as Einstein's general and special theories of relativity, and more, including features describing the origin of life. The graphics and animations are stunning, and Hawking's voice lectures to you from your very own computer.

Life in the Universe is bundled with Microsoft's Internet Explorer and can be configured by individual users to link directly to a regularly updated Internet website for access to links and more information. Additionally, it contains two interactive games, five full-text articles from *Scientific American,* 50 QuickTime movies, and several more features.

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Classroom activities are a part of the extensive educational resources, and short biographies of leading space scientists are included as well. If you're still not sure, there's more. Also packaged in *Views of the Solar System* are Microsoft's Internet Explorer and Video for Windows, along with Adobe Acrobat Reader.

National Science Teachers Association, 1840 Wilson Boulevard, Arlington, VA 22201-3000; phone, (703) 243-7100, (800) 722-NSTA; fax (703) 243-7177; website, http: www.nsta.org. Price: $21.95. Supports both Mac and PC platforms.

An issue of *Astronomy* that highlighted photographs of the solar system in 3-D has proven to be a hit with readers (March 1998), and I love it, too. For more great images, try *3-D Tour of the Solar System*, which comes with 3-D glasses to view 160 spectacular 3-D images created by Lunar and Planetary Institute's Paul Schenk, David Gwynn, and James Tutor.

From the sun's fiery surface to the dancing rings around Saturn, hurricanes, craters, mountains, and canyons seem to reach out and touch you in three dimensions.

Not only is this CD-ROM entertaining, it's also educational. *3-D Tour of the Solar System* includes tables of scientific data, geological descriptions, space mission descriptions, and a glossary of geologic terms. The entire family will get involved with this program. It might even pull the kids away from their Sony PlayStations.

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Converting the

Couch Potatoes

Here are some hints that help teach the sky as entertainment.

by Andrea Gianopoulos

Life on other worlds, black holes, supernovae, and cannibalistic galaxies — these are just a few of the astronomical subjects that can spark the imagination and bring out a childlike quest for discovery in us all. The question we must answer is how to light that initial flame inside today's couch (and mouse) potatoes. Can the night sky truly compete with the fast-paced images thrown at us from a television or computer screen? You bet it can. In fact, the media help to ignite that spark. Astronomical discoveries are frequently seen on the nightly news and on the front pages of the leading newspapers and magazines. Astronomy also has a tremendous presence on the World Wide Web. The interest is obviously there. The flame just needs to be fanned.

One organization helping to bring that spark to a roaring fire is the Astronomical Society of the Pacific. Their Project ASTRO program pairs fourth- through ninth-grade teachers with local amateur and professional astronomers. After completing an initial training process, which includes age-appropriate teaching techniques, the astronomers are given audiovisual and written materials to take into the classroom. There they lead hands-on activities, assist with student projects, and organize evening star parties.

The Universe at Your Fingertips, Astronomical Society of the Pacific

Astronomy: Andrea Gianopoulos

Brian Loomis gives his report on the planet Jupiter to classmates at Butte Des Morts school in Menasha, Wisconsin.

The hands-on activities include fun topics like Staying Up While Falling Down, The Reasons for the Seasons, Sun and Star Clocks, How High Can You Jump on Another Planet?, Your Galactic Address, Planet Bingo, and many others. These activities focus on the basics of astronomy and the scientific process. They allow students to discover astronomy for themselves while dispelling many common misconceptions. The Reasons for the Seasons, for example, is an activity that addresses how and why we have four different seasons; it uses observations and 3-D modeling to bring home the point that our seasons are caused not by our distance from the sun (a common misconception), but by Earth's axial tilt.

To begin the activity, students observe the sun's motions through the sky. They measure and chart the sun's altitude above the southern horizon on the summer and winter solstices and at the autumnal and vernal equinoxes. Because of time constraints, this is usually done in a planetarium.

The second half of the activity models Earth's motions with respect to the sun. Each student has a 3-inch polystyrene ball with a pencil or stick through the center to represent Earth's axis. A bare light bulb is placed in the center of the room to symbolize the sun. The students tilt their polystyrene Earths 23.5° along the pencil axis while spinning them counter-clockwise to depict our daily motion. They watch the sun's light move across their makeshift Earths and in the process gain a better understanding of why the sun appears to move across the sky as it rises and sets. They also move around the light bulb, simulating Earth's yearly motion around the sun. Such active modeling gives each student a three-dimensional picture of how things work. They can see firsthand why Earth's tilt causes the Northern Hemisphere to receive the sun's light more directly during the summer months and indirectly during the winter months.

Displacing such misconceptions is an important part of astronomy education. None of our minds are blank slates waiting to be filled with a

So What Can I Do?

Here are a few suggestions to help you spark an interest and dispel some misconceptions.

- If you have a telescope, organize a neighborhood star party. Convince everybody to turn off their lights and come outside for an evening of discovery. Point out the brightest stars, constellations, and any planets that might be visible. If you don't own a telescope, ask everybody to bring a pair of binoculars.

- Get involved by visiting schools and youth organizations. Most amateur astronomers have a wealth of knowledge and enthusiasm to impart, and children are the perfect students. After nearly 15 years as an astronomy educator, I have yet to find a child who is not interested in some aspect of space.

- Volunteer at a local planetarium or science center. Enthusiastic, knowledgeable people are always welcomed.

- Take a cue from amateurs in the San Francisco Bay area and become a sidewalk astronomer. On a clear evening with a first quarter moon, bring your telescope to a park or downtown sidewalk or parking area. The moon is an impressive sight through a telescope, even through the colors of the setting sun at twilight.

- Teach a class on the joys of stargazing at a local community center or library. You don't have to get into celestial mechanics and plasma physics. Just teach the basics: how to find the constellations, the difference between stars and planets, why the moon has phases. If interest is high, you can conduct a second class on binocular astronomy.

- Simply share your enthusiasm and knowledge.

wealth of knowledge. Our experiences, observations, and preconceived notions mix and mingle until they develop into our own personal view of the universe. A good example of that can be found in the origins of astronomy as a science.

Our ancestors were watchers of the night sky. Their ideas of the universe were based on observation and experience. They saw the sun, stars, moon, and planets rise in the east and set in the west. Earth appeared to be at the center of the universe. The sun gave light, heat, and life; the dark night sky glittering with stars produced emotions of awe, wonder, and fear. Our ancestors relied on celestial signals for sustenance. The sky told them when to plant and harvest crops, hunt game, or forage for wild fruits and nuts. Survival and curiosity drove them to better understand the important cycles taking place in the sky above. They sectioned the night sky and connected the dots to create constellations with elaborate myths that focused on cultural stereotypes, fears, and taboos. They learned to chart the heavens and attributed the good and bad episodes of their lives to events in the sky. This mixture of early science and nescience developed into the practice of astrology, which led eventually to our modern science of astronomy.

Today's astronomical misconceptions are similar to the misinterpretations of the past. Research has shown that many children believe Earth is round and flat like a pancake. If pressed to explain pictures they've seen of Earth from space (in which it appears spherical), they qualify their answer by explaining that round Earth is where the astronauts go — somehow different from the flat Earth we live on. They have been told that Earth is a sphere, but their personal experience and observation tell them otherwise.

Such misconceptions aren't limited to children. In a video entitled *Private Universe* researchers from the Harvard-Smithsonian Center for Astrophysics asked graduating Harvard seniors, faculty, and students from a first-rate high school questions like why the moon shows phases. A typical answer was that Earth's shadow and clouds block out the light from the sun, creating the different moon phases. It's frightening to think that such basic astronomical knowledge is not understood by college graduates and some faculty members of such a prestigious institution. So, what can be done about it?

The answer may come from teaching methods. For years the media has told us of the country's troubles in science education and instruction. When our children's science proficiency is compared to that of European and Asian students, we always fall short. One reason for the discrepancy is teaching style. Though it is changing, the dominant teaching method for science and math in the United States is transmission, a method that exposes students to new material through readings, lectures, and presentations.

We all know the drill: Read the chapter, attend the lecture, watch the instructor do the demonstration, memorize what the instructor said, spit it back out during the exam, you get the "A." Unfortunately, many of these "A" students are incapable of displaying an understanding of the concepts involved. And all too often, because they do not understand the underlying concepts, students don't retain the knowledge gained through rote memorization.

First-grader Hailey Hackbarth studies 3-D images of her favorite planet, Mars. She visited Mars in her Space Journal, taking care to bring lots of turkey and mustard sandwiches for the long journey.

Astronomy: Andrea Gianopoulos

The problem with the transmission method comes from an assumption that students are getting the message the instructor intended. If the students don't understand, the instructor tries to present the concepts more clearly by speaking more slowly or by presenting the material in a different manner. Sometimes the message gets through, but more often the student shuts down from system overload. It all comes back to that blank slate. People can't simply be filled with the knowledge we want them to have. Human beings need to experience the science in order to more fully understand its concepts.

Experience, on the other hand, is the pivotal point used in a different method of education known as constructivism. It claims that students are not blank slates waiting to be written upon or sponges waiting to absorb, but instead it maintains that all of our knowledge is the direct result of our minds having constructed it. In other words, our knowledge and experience influence how we interpret new observations and information. It focuses instruction on relating new concepts to previously learned knowledge and experience so students can build a steady picture of the world around them.

Constructivism is the exact opposite of transmission. It directly addresses one's private view of the universe and allows the instructor to play the role of facilitator instead of transmitter. During the lesson, the teacher probes the students' knowledge base and understanding for misconceptions. At the same time, the teacher helps the student resolve any conflicts that arise between new concepts

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For links to these sites as well as others visit Astronomy at: http://www.astronomy.com and prior knowledge. This is done by encouraging debate and discussion, suggesting events that contradict the students' beliefs, and guiding students toward the correct interpretation. Constructivism recognizes that learning is a process. The communication between student and teacher becomes an exchange of information and not a funnel of concepts the student has to absorb.

Though it seems like the solution, constructivism is not without its problems. It takes time to root out misconceptions during the teaching process — and in fact many such misconceptions will disappear naturally as the students grow and learn. Another problem comes from the knowledge base of educators. To practice this method of teaching, an educator must know the subject matter very well. Can we expect teachers to focus on astronomy education when in many schools their primary objective is to make sure Johnny can read, write, and function in society?

Another element that works against astronomy education is the very nature of the subject. After all, learning astronomy is like learning a foreign language, literally. The majority of constellation names are Greek and Roman, and the star names are primarily Arabic. Every time I hear the constellation Ophiuchus (Oh-fee-YOU-kus) roll off of somebody's tongue, I feel the need to say "Gesundheit" or "God bless you." Then there are constellations like Scutum — which sounds like some internal organ you never knew you had — and Horologium — could it be a chamber of horrors? In reality, these constellations are quite bland. Scutum is a Shield and Horologium a Clock. As for Ophiuchus, he is the Serpent Bearer who is often identified as the god of medicine. Fortunately, we can use these names and their mythology to our advantage. The extensive lore and mythology that has long been a part of astronomy helps convert a massive base of information into more digestible stories and tales — all of which serve as mnemonic devices to simplify the process of coming to know the countless stars in the sky. Additionally, the stories that accompany the constellation names help entice would-be star gazers: Fanciful and entertaining narratives woo children and adults alike into looking skyward.

The link between astronomy and the humanities can also be brought in to whet students' appetites. Many works have been inspired by the heavens and a fun exercise might be to trace the evolution of astronomical ideas through literature, art, poetry, and music. These compositions offer a great starting point for discussion. In the case of music, Gustav Holst's "The Planets" is a prime example. The work conveys a sense of the planets through sound. Each tune can be identified by knowing the physical nature and mythology behind the planet it represents. For those whose taste leans toward modern rock, the Canadian group Rush sings of a ship traveling through a black hole in the song "Cygnus X-1" on *Fare Well to Kings*. The lyrics include an accurate passage on the relative positions of Lyra, Pegasus, Deneb, and Cygnus. Another example is the song "39" from *A Night at the Opera* by Queen. Here students can experience astronomer and band member Brian May's musical representation of relativistic space travel. Such connections make the sometimes ambiguous concepts of astronomy more real to students, and they can definitely make it more fun.

Astronomy: Andrea Gianopoulos

Beautiful images of planets, galaxies, and nebulae can link art to astronomy. In this photo, Chloe Jankowski shows the rendition of Jupiter's symbol that she and her teammates prepared for their talk.

Movies have long offered fodder for astronomy education — though they are often more full of scientific error than fact. But even Hollywood's gaffes can be put to good educational use. Why not take a videotaped astronomy-based movie and play it to a group of students? With each less-than-realistic portrayal of space or astronomy, stop the tape and don't start it again until someone can pinpoint the mistake. Again, this technique helps involve students actively, allowing them to learn through experience rather than through absorption.

Where astronomy education is concerned, there's really only one important lesson to be learned: Teach, don't preach. Invite, entice, encourage students of all ages to learn about astronomy by offering them experiences that allow them to understand concepts and ideas through participation. The universe is all around us, and usually all it takes to generate interest in astronomy is for educators to help students discover that for themselves. ◼

Andrea Gianopoulos is an associate editor for Astronomy *magazine. One of her greatest joys is teaching astronomy to children of all ages.*

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"Consistently performed well on all emission and planetary nebulae. Detail and structure were greatly enhanced in the more than two dozen objects I viewed." ***SKY & TELESCOPE*, July 1995**

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SEE THE HORSEHEAD!

*"**LUMICON's H-Beta Filter** will show subtle features in emission nebulae that the others fail to reveal. It can't be beat for the elusive Horsehead and California nebulae. . ."* ***SKY & TELESCOPE*, July 1995**

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Rich Zepernick saw the Veil Nebula for the very first time with a **LUMICON UHC Filter**. He stated, *"It was actually there! and not just around 52 Cygni, but the whole loop! Words cannot possibly express my feelings. I don't know how I managed without these filters."*
Rich Zepernick, Cresskill, NJ

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BEST for Astrophotography!

"Stunning is all I can say," says noted astrophotographer Jack Newton. Great for BOTH color and black and white photography.

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*"Based on our tests we'd recommend a LUMICON Deep-Sky and Oxygen-III as complementary filters. The LUMICON Deep-Sky Filter clearly had the best contrast for **reflection** nebulae."* ***ASTRONOMY*, February 1991**

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**Premium filters are currently the best in the world. All Lumicon filters include individually measured transmission data.*

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DEEP-SKY ASTROPHOTOGRAPHY

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†U.S. Patent 4,473,636

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4. **Dual-axis drive corrector** for telescope. This should be part of the telescope when purchased. Call LUMICON for details.
5. **LUMICON EASY-GUIDER** (selection to left) .
6. **LUMICON 48mm DEEP-SKY FILTER $199.50** This is essential for highest possible contrast. Contrast is boosted up to 3X for ***both*** color or black & white photos. The 3 photos in this ad showing the Helix Nebula, Horsehead Nebula and Veil Nebula were all made using a LUMICON 48mm DEEP-SKY FILTER.
7. **Hypersensitized film.** Purchase from LUMICON or make your own with a LUMICON HYPER-KIT.

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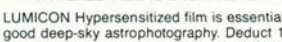

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LUMICON Hypersensitized film is essential for good deep-sky astrophotography. Deduct 10% for 3 or more rolls (mixed o.k.). ***No C.O.D.s.***

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Fuji G800 fine grain color neg.	**24**	$13.95
Ektachrome 1600, fast slide film	24	$14.95
Fujichrome RD100, fine grain slide	24	$12.95
D-19 B&W Developer	1 gal.	$8.50

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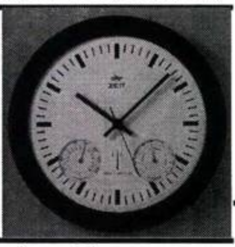

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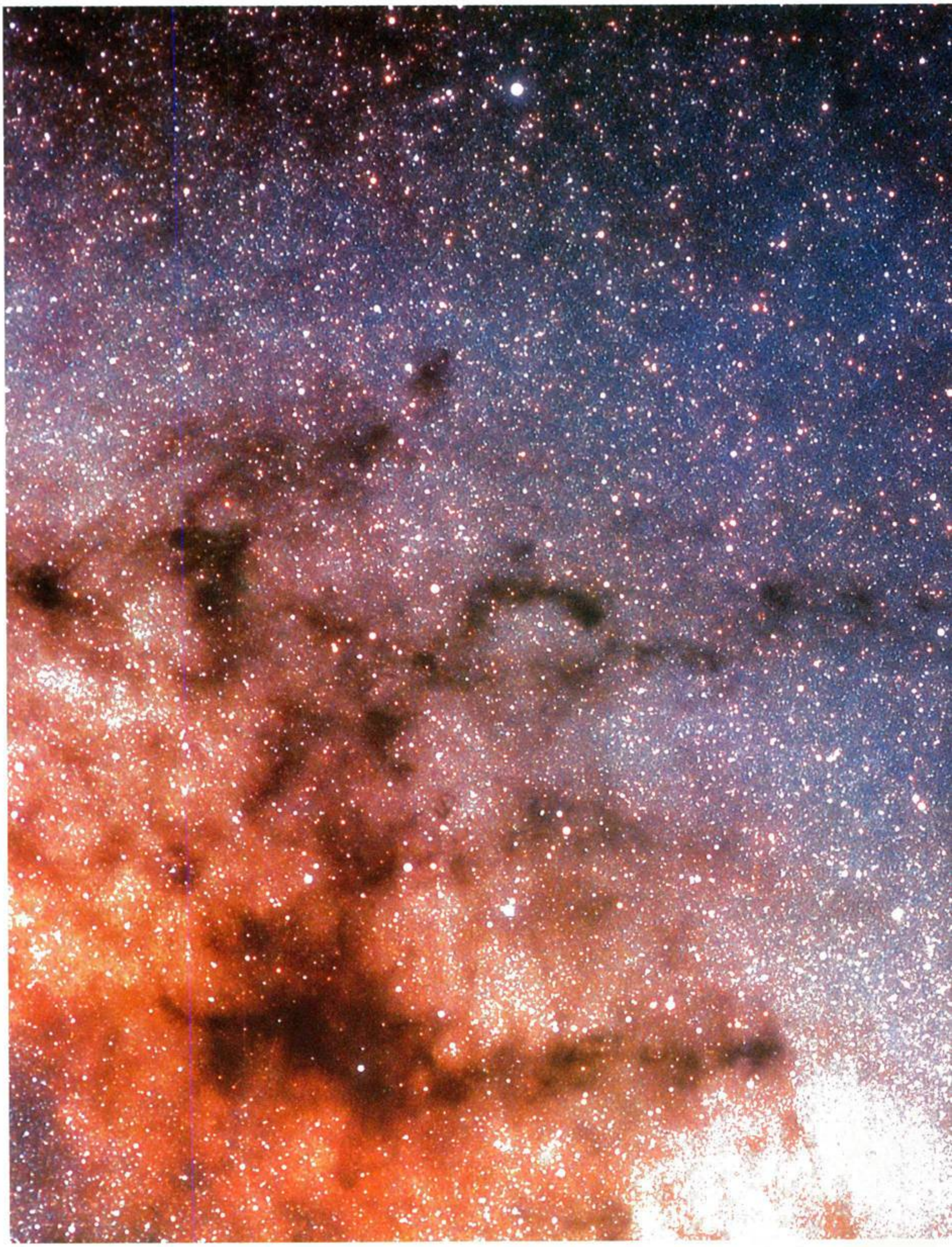

l Universe

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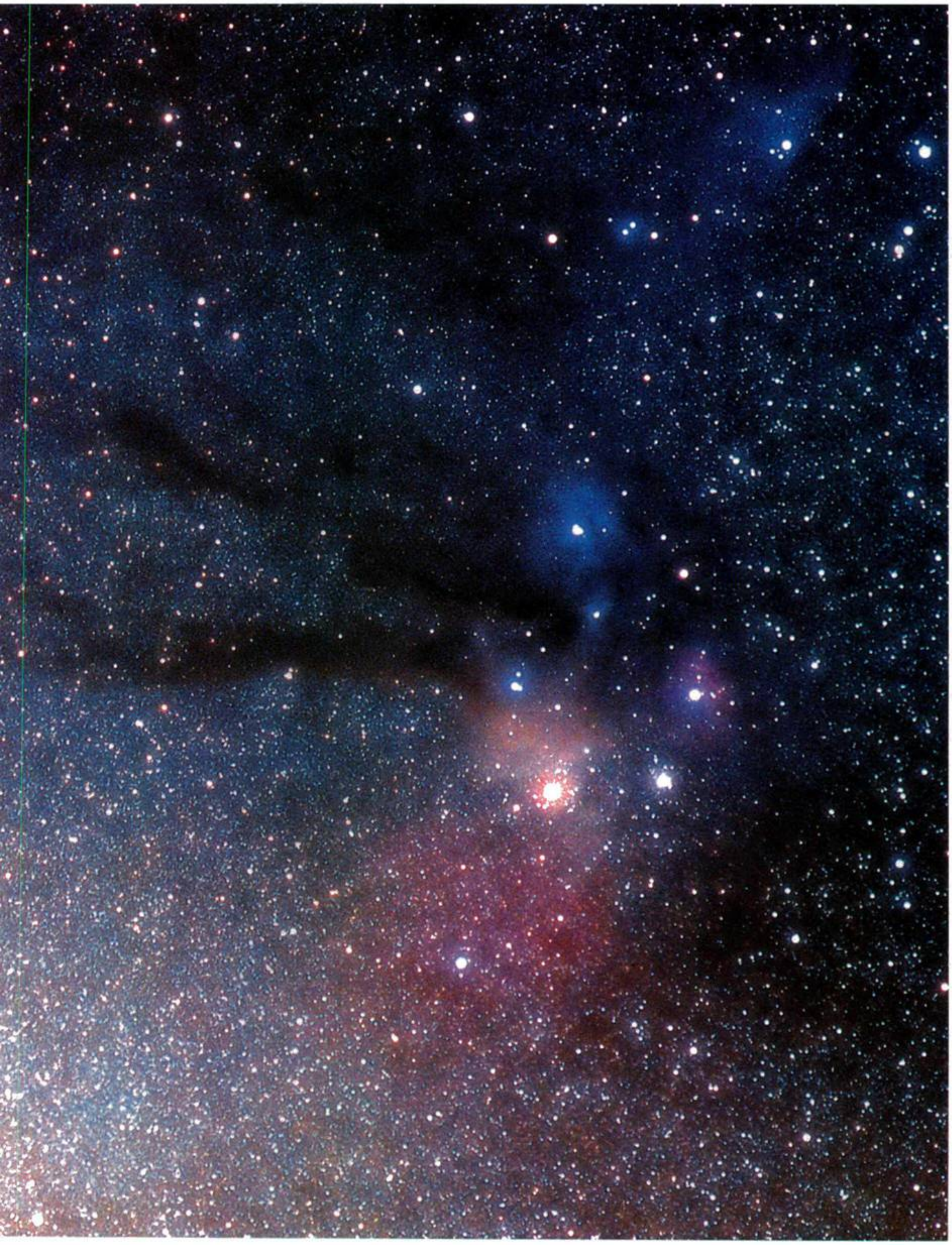


The Pipe Nebula (B78)

JERRY LODRIGUSS

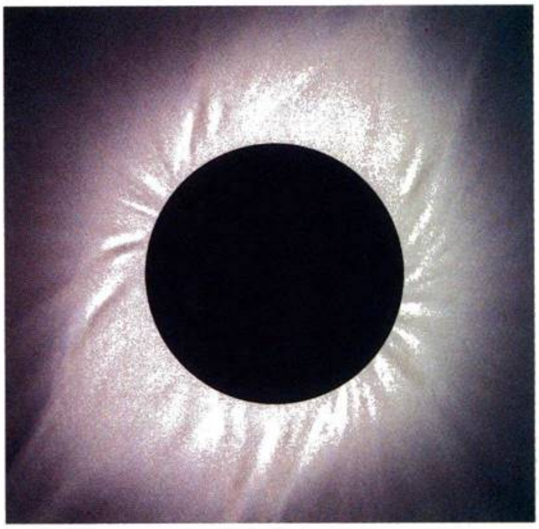
Turn this photo 90° clockwise to see a great dark horse; the well-known Pipe Nebula accounts for the lower half of the horse's body. (85mm lens at f/2.8, hypersensitized Fuji Super HG 400 film, composite of two 15-minute exposures)

Coronal Streamers

H. J. P. ARNOLD

Because the sun is normally so bright, the coronal streamers are visible to the naked eye only when the sun is totally eclipsed by the moon.

(1000mm lens at f/11, Fujichrome 100 RD film, composite of six exposures ranging from ¼ second to 4 seconds taken February 26, 1998)

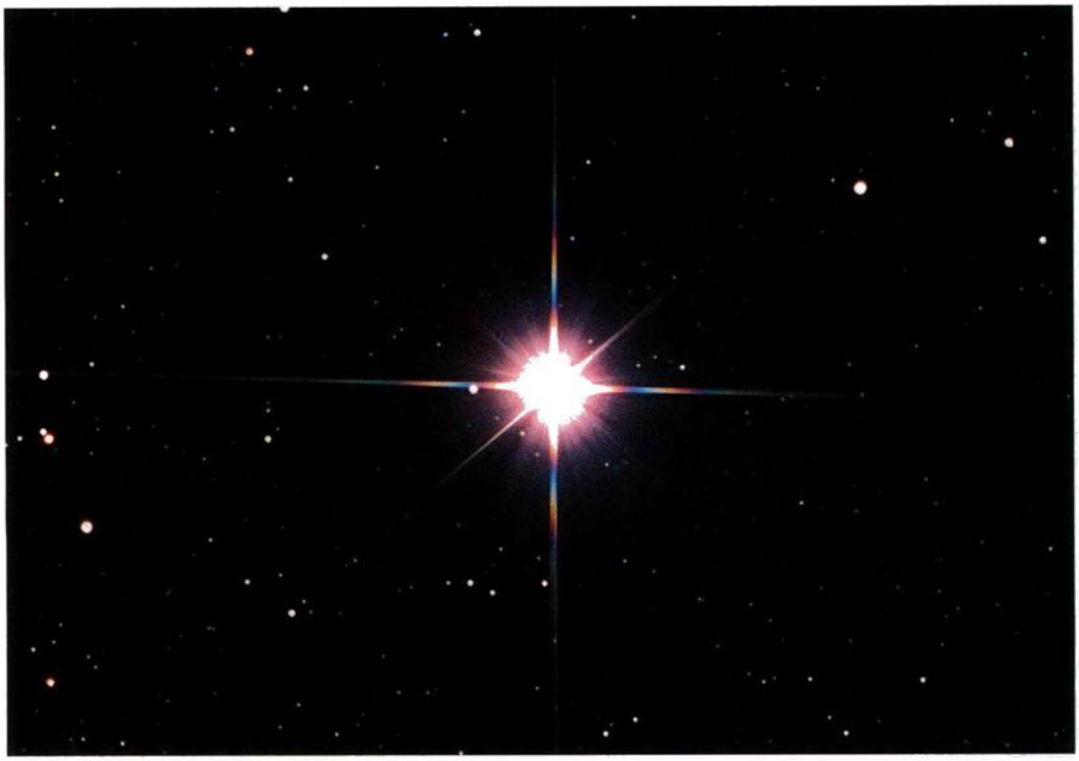


The Great Andromeda Galaxy (M31)

MIKE FIEST

The largest member of the Local Group of Galaxies, this enormous spiral is shown here with elliptical galaxies NGC 205 (to its right) and M32 (to its left).

(6-inch f/7 refractor, hypered Kodak PPF film, composite of two 75-minute exposures)



Capella in Auriga

JOHN CHUMACK

The sixth brightest star in the sky, Capella gleams brightly at a distance of 45 light-years.

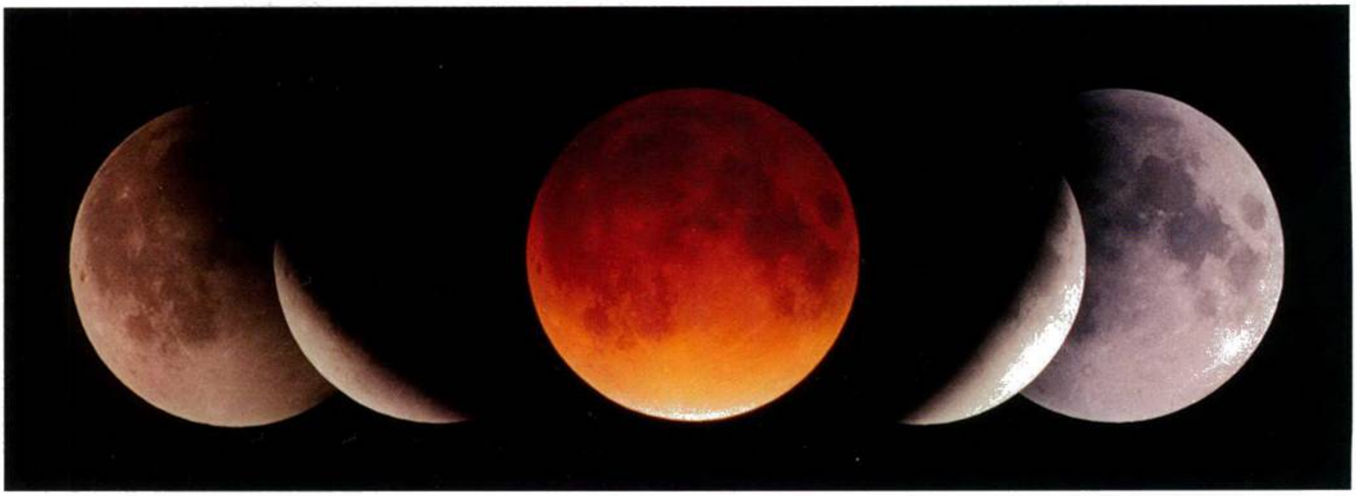
(16-inch f/4.5 reflector, Kodak Royal Gold 100 film, 30-minute exposure)

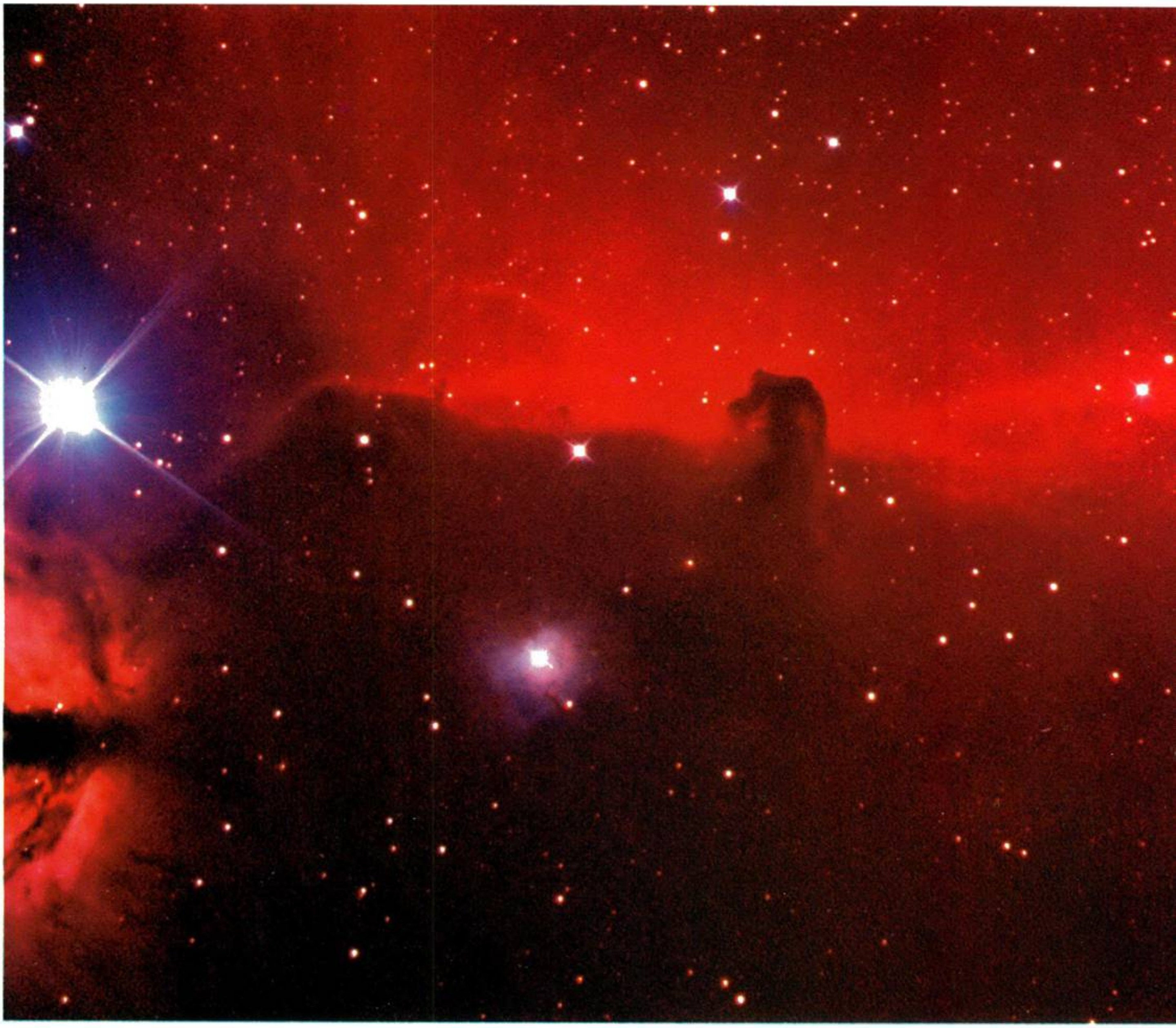
Lunar Eclipse Medley

CHUN-KI PARK

The lunar eclipse of September 17, 1997, fell on the holiday Chu-Sok in Korea, when many people were interested in observing it.

(4-inch f/8 refractor, Kodak Ektachrome E100SW film, composite of five exposures ranging from 1/250 second to 15 seconds.)





The Horsehead Nebula in Orion

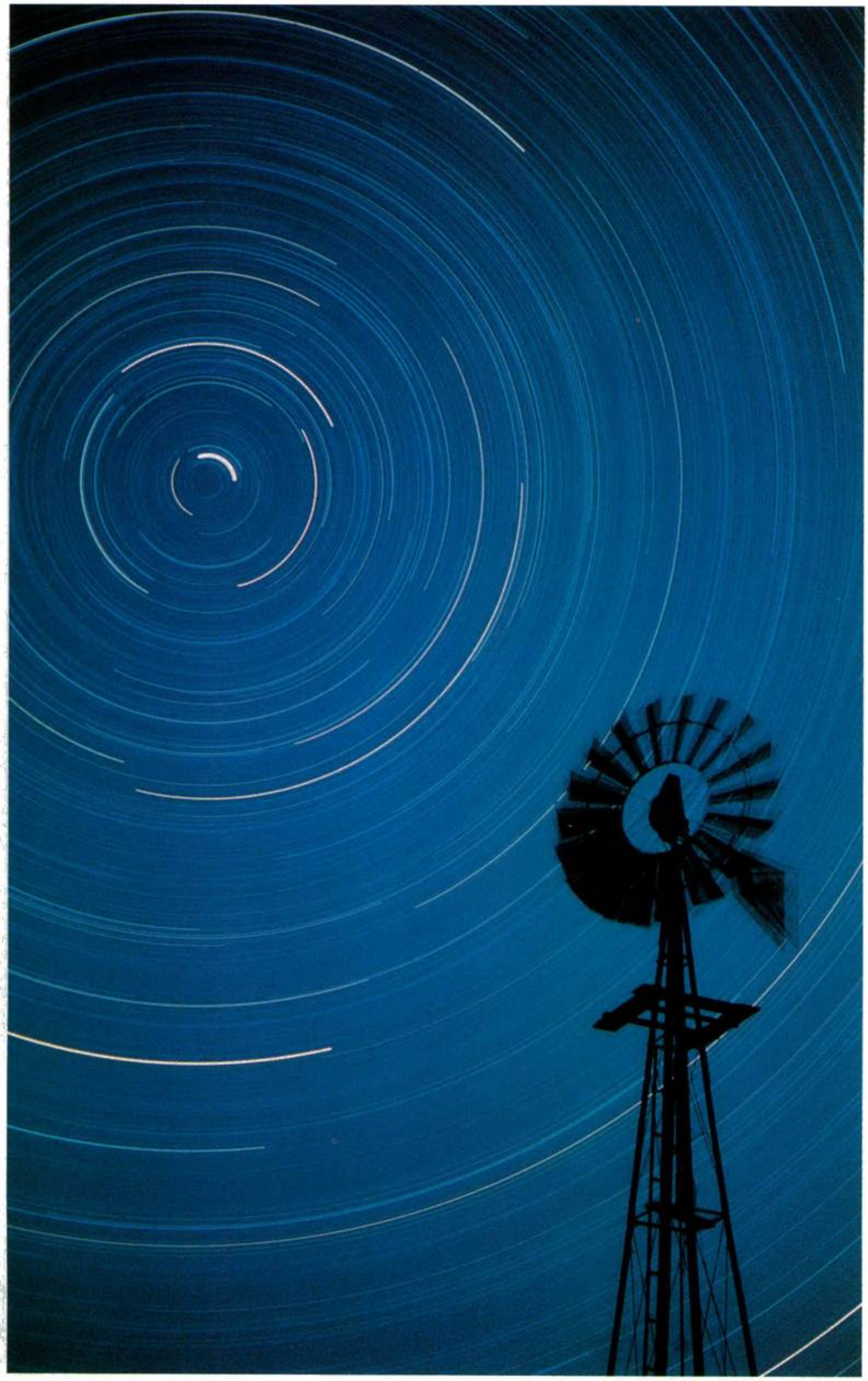
CHRIS SCHUR

Not the easiest telescopic target to spot, the Horsehead, once seen, is never quite forgotten.
(12.5-inch f/5 reflector, Kodak Multispeed 640 PJM film, composite of two 60-minute exposures)

Southern Neighbors

BRUNO MATTERN

First recorded by Ferdinand Magellan in 1519, the Large and Small Magellanic Clouds are close neighbors of our own galaxy. They are visible only from the Southern Hemisphere.
(50mm lens at f/4, Kodak P 1600 film, 20-minute exposure)



Spinning Wheels

JOSHUA VAUGHAN

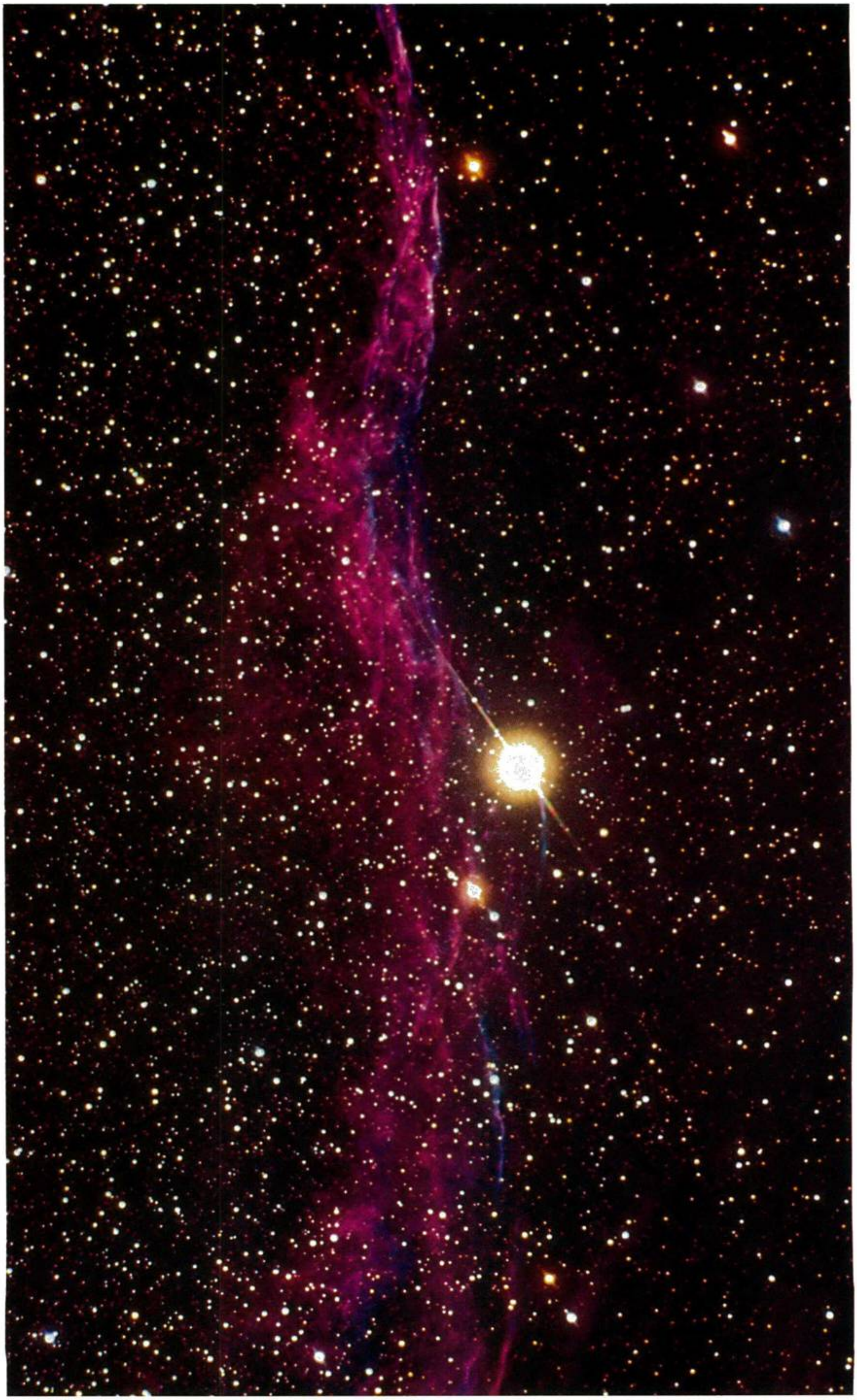
A windmill on an old ranch in Arizona's Prescott National Forest beckoned to the photographer during a drive in the deserted country.

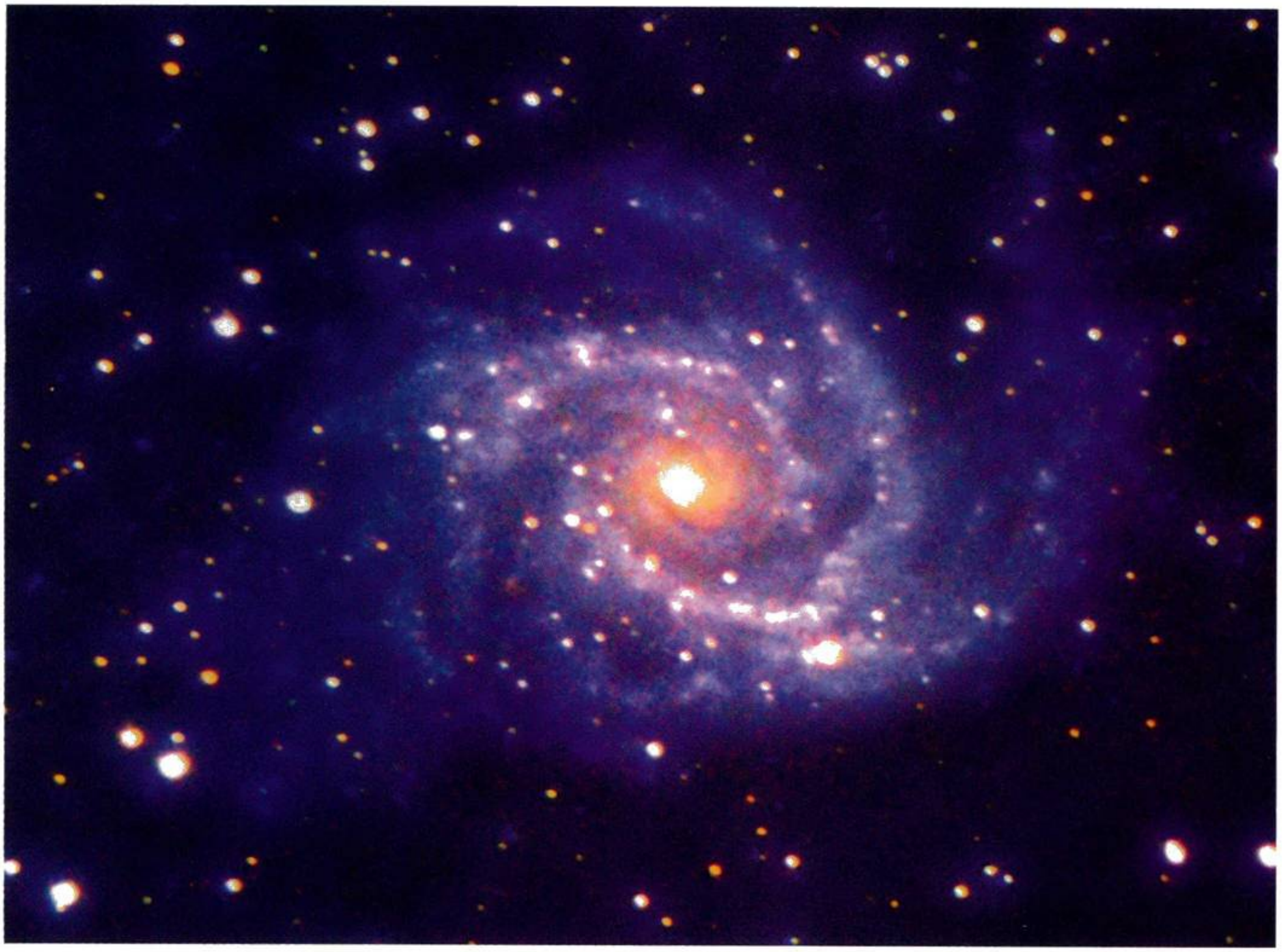
(75mm lens at f/4.5, medium format camera, Fuji 100 film, 5-hour exposure taken June 6, 1997)

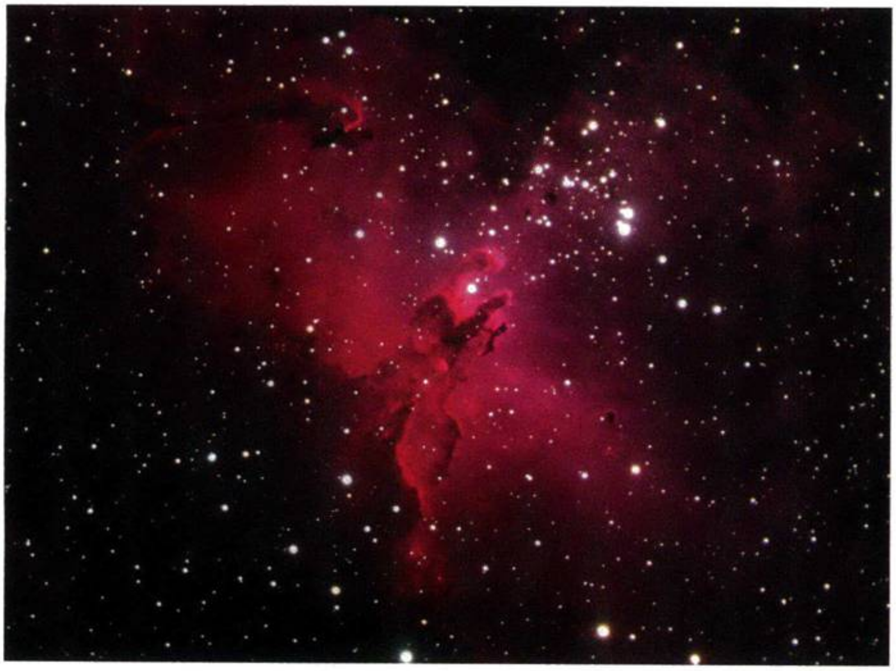
52 Cygni Unveiled

BILL AND SALLY FLETCHER

A portion of the Veil Nebula in Cygnus appears to wrap itself around the star 52 Cygni. *(16-inch f/4.5 reflector, Tech Pan film, tricolor composite of 72-minute red, 95-minute green, and 135-minute blue exposures)*



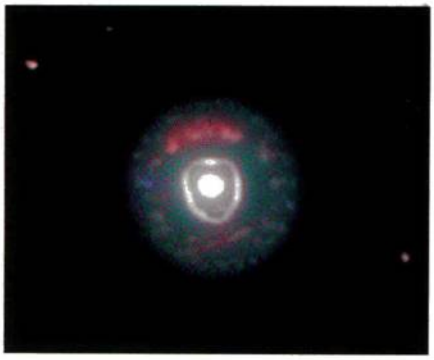




NGC 2997 in Antlia

JAMES FOSTER

The southern skies host this spiral galaxy, NGC 2997, located in Antlia the Water Pump.
(11-inch SCT at f/11, hypered Tech Pan 2415 film, composite of 105- and 63-minute exposures)



The Eskimo Nebula (NGC 2392) in Gemini

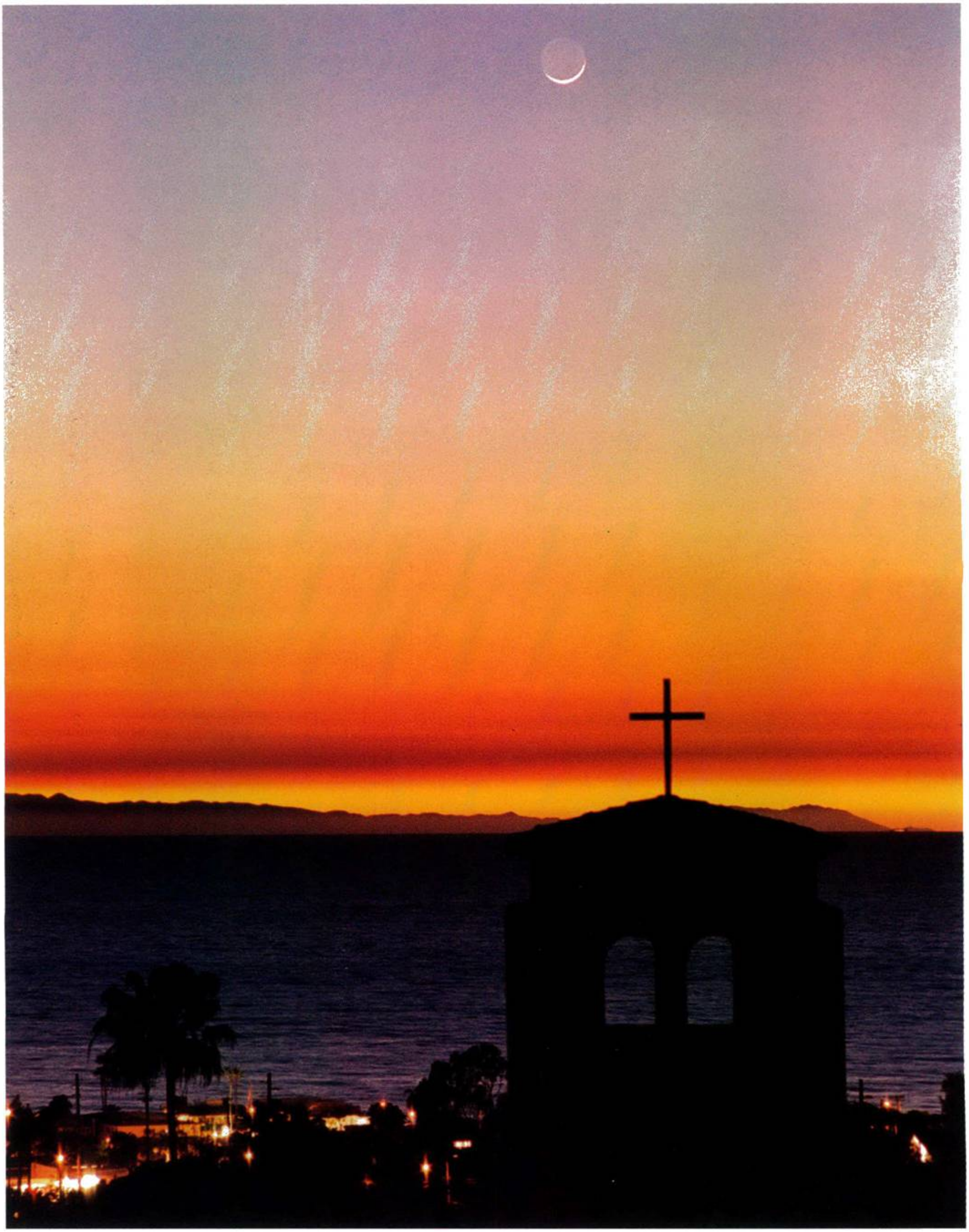
ED GRAFTON

This planetary nebula's name comes from its resemblance to a parka-like hooded face.
(14-inch SCT at f/7, ST-5 CCD camera, composite of 11-minute monochrome, 7-minute red, 15-minute green, and 21-minute blue exposures)

The Eagle Soars

DAVID HANON

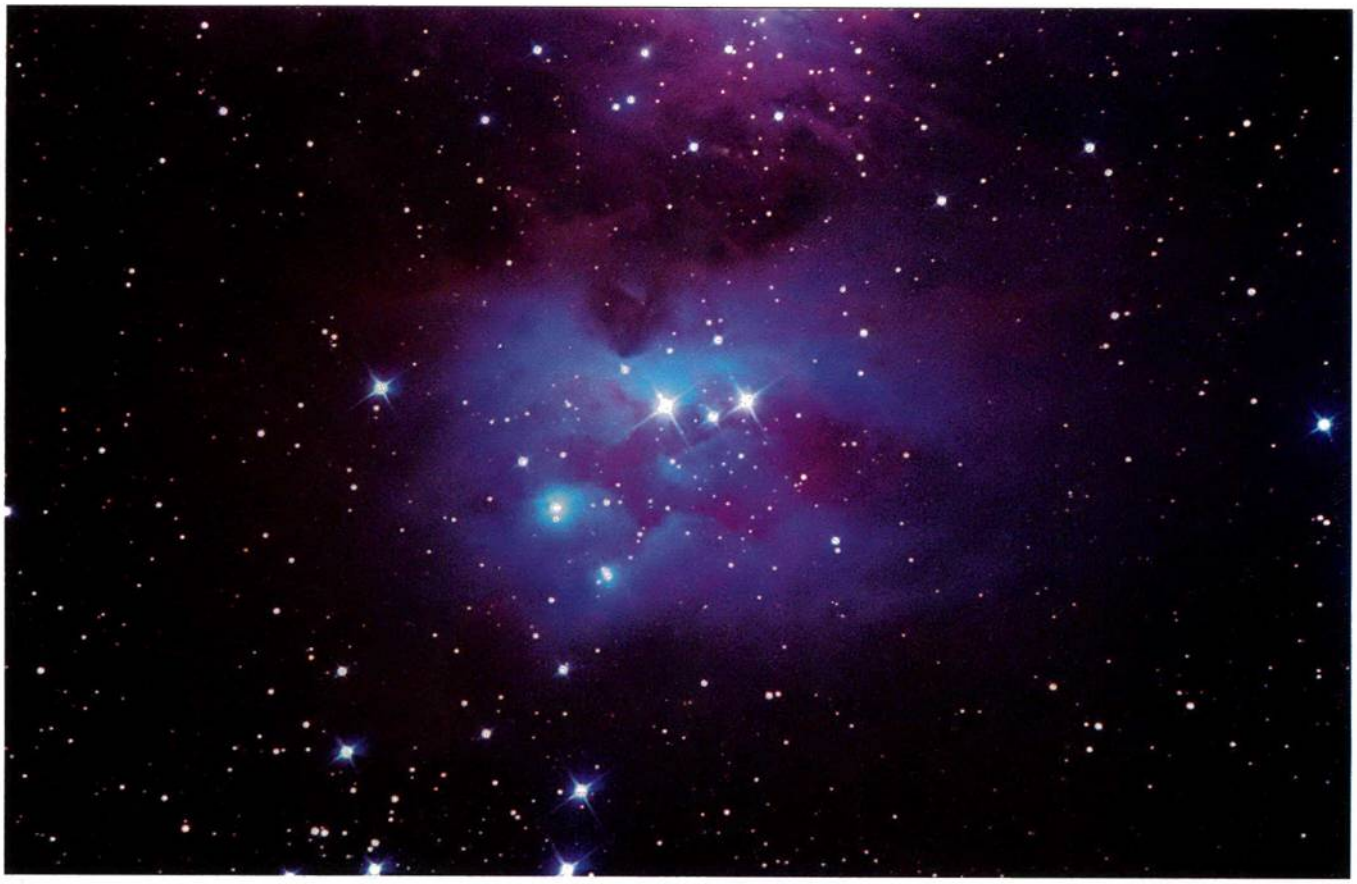
The aerie of the Eagle Nebula (M16) is nestled in the constellation Serpens.
(7-inch refractor at f/9, ST-8 CCD camera, composite of 21-minute red, 21-minute green, and 52-minute blue exposures)

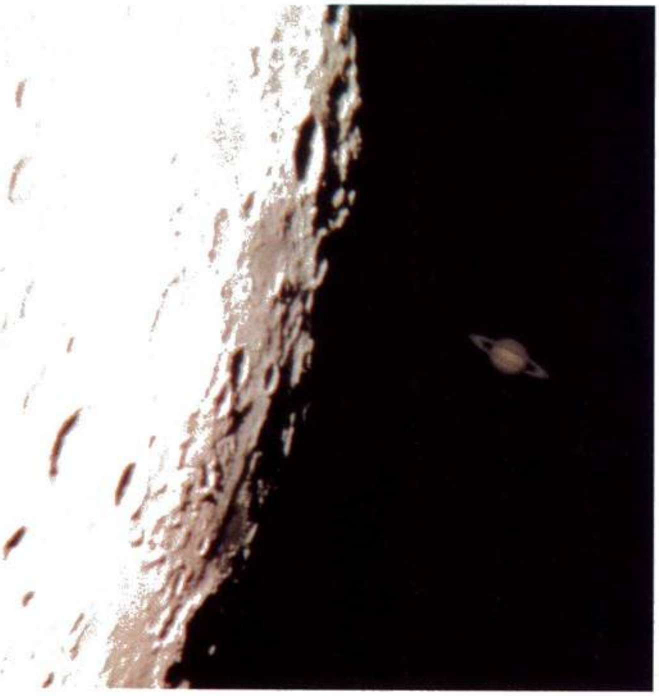


A Young Moon off Laguna Beach, California

CHRIS COOK

(105mm f/4 lens, Kodak Gold 100 film, 2-second exposure taken February 27, 1998)





NGC 1973-75-77 in Orion

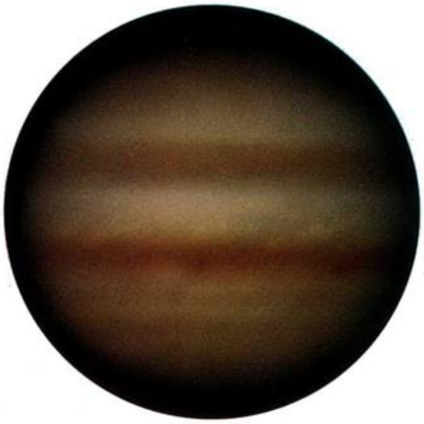
CHRIS SCHUR

The nebulosity around the northern tip of Orion's sword is illuminated by the open cluster it surrounds. *(12.5-inch f/5 reflector, hypered Kodak Pro 400 PPF film, composite of two 45-minute exposures)*

The Gas Giant Jupiter

LEROI TEIVA

(11-inch SCT at f/90, Fujichrome 100 film, composite of two 2-second exposures taken in August 1997)



The Moon Occults Saturn

CHRIS COOK

When the moon passes in front of a planet, the photographer is challenged to record the planet's detail while still maintaining some features on the much brighter moon. *(8-inch f/10 SCT at 97x, Fujicolor Super HGV 400 film, 1-second exposure taken September 18, 1997)*

Yukon Dawn

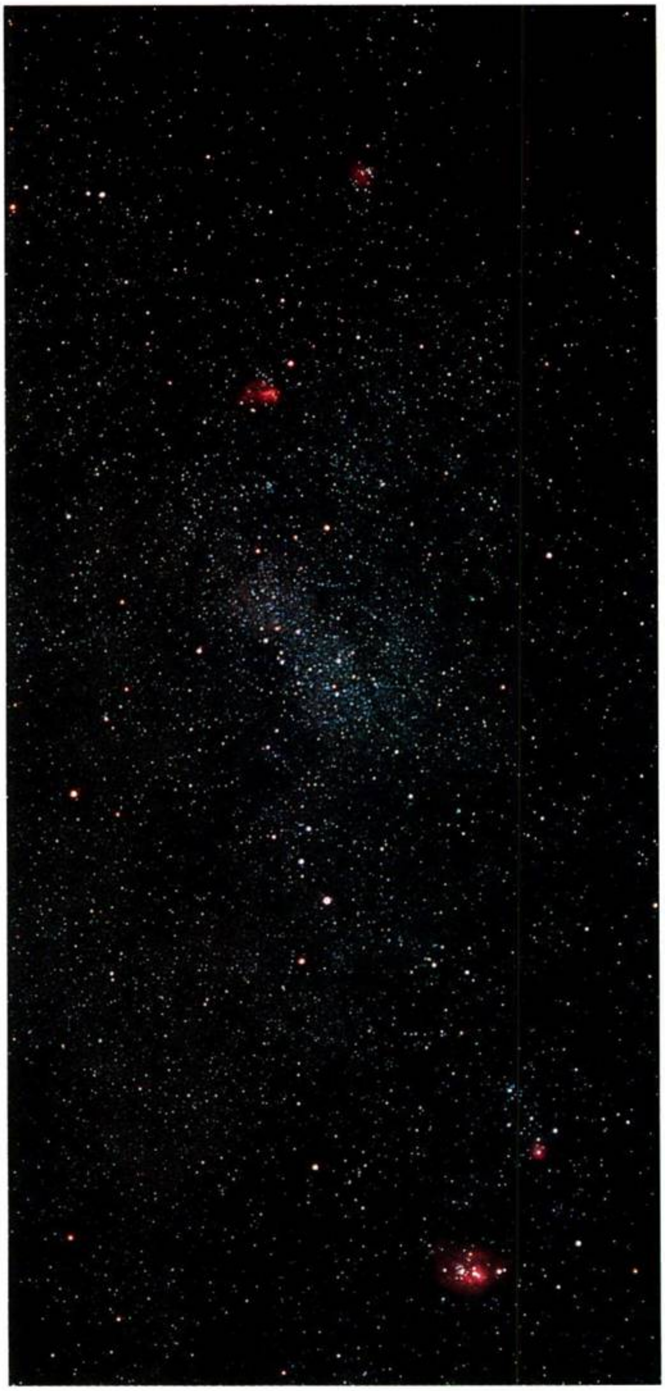
W. A. MERCER

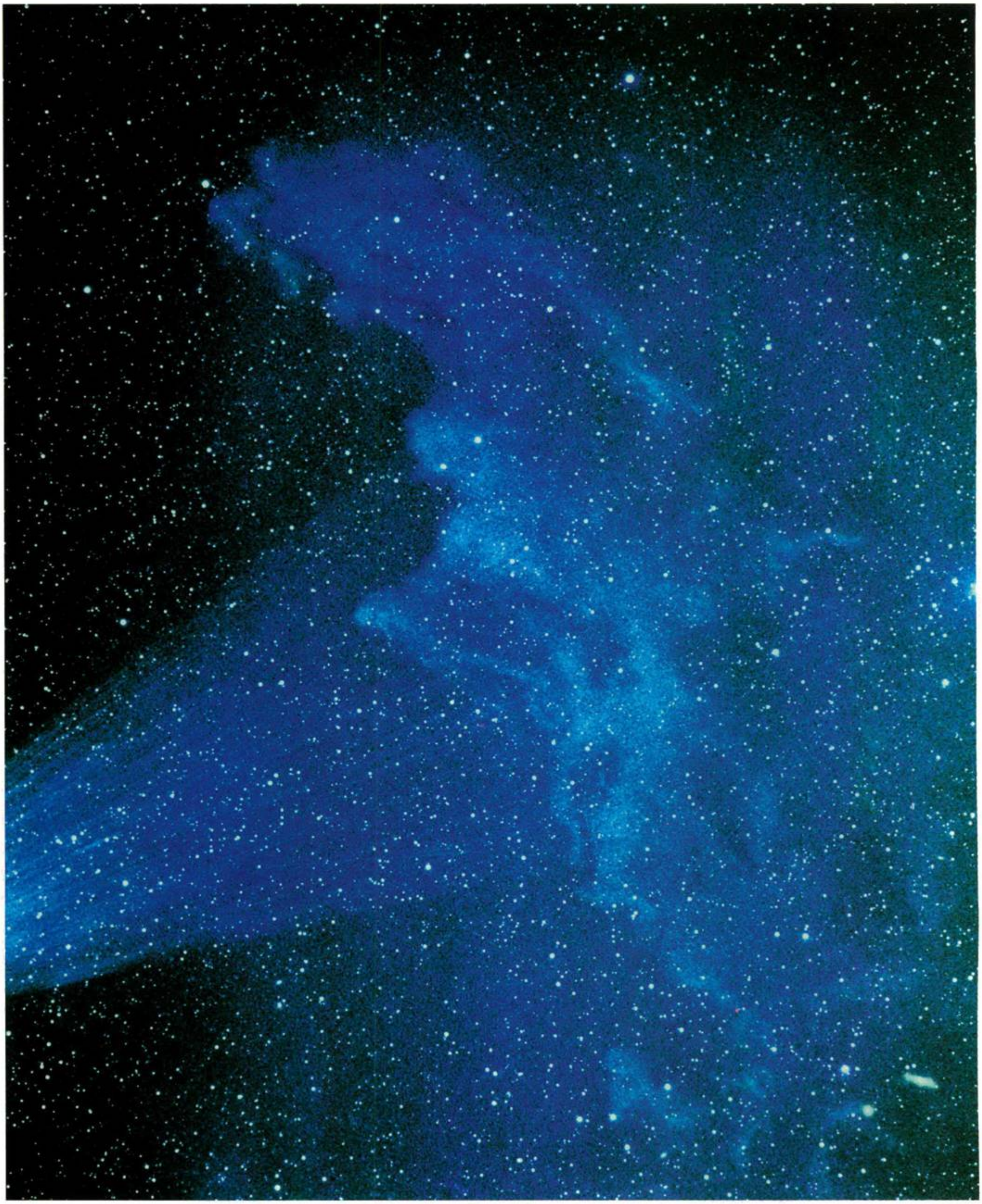
A memorable display of Aurora Borealis paints the predawn sky of White Horse in the Yukon of Canada. *(55mm lens at f/2.8, Fuji Super G Plus 800 film, 20-second exposure taken September 15, 1996)*

From the Archer's Quiver

TIM BARNWELL

The Sagittarius region is aglow with rich nebulae. Clockwise from the top are the Eagle Nebula, M16 in Serpens Cauda; the Omega Nebula, M17; M8, the Lagoon Nebula; and M20, the Trifid Nebula. *(135mm lens at f/2.8, Ektachrome 400 film, 10-minute exposure)*





The Witch Head Nebula (IC 2118) in Eridanus

TONY AND DAPHNE HALLAS

This mesmerizing nebula lies about 10° east of the hot blue star Rigel, from which direction the flare is visible. NGC 1752, a comparatively tiny spiral galaxy, lies in the lower right of the photo.

(7-inch f/7 refractor, hypered Vericolor PPF film, composite of two 60-second exposures)

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7" LX200 Maksutov-Cassegrain	**3295.**

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- **Meade LX200 High-Precision Pointing**™ is so precise it permits the positioning of *every* selected object on *every* commercially-available CCD chip *every* time, automatically — *a feat that no other telescope priced under $40,000 can accomplish.*

- **Permanently-Programmable Smart Drive**™ routinely achieves 5 arc. sec. periodic error, an observatory standard.

- **9-Speed Dual-Axis Electronics:** Electronics that cover every possible contingency of telescope positioning—from 2x photo-guide, to 32x image centering, to 8°/sec. slewing across the sky, plus 6 dual-axis drive speeds in between.

SPECIFICATIONS: 7", 8", 10", and 12" LX200's—Each complete telescope includes 8" or 10" (f/6.3 or f/10) or 12" f/10 Schmidt-Cassegrain or 7" f/15 Maksutov-Cassegrain optical tube assembly with EMC super multi-coatings; heavy-duty fork mount with 4" polar ball bearing, dual-axis 5.75" worm gears, and multi-function control panel; manual and electric slow-motion controls on both axes; keypad hand controller with digital readout display, permanently programmable Smart Drive, 9-speed drive controls on both axes (7-speed on 12"), High-Precision Pointing, and GO TO controller; 64,359-object onboard celestial software library; 25 ft. power cord and adapter for telescope operation from 115v.AC; 8 x 50mm viewfinder; 1.25" diagonal prism (7", 8", 10") or 2" diagonal mirror with 1.25" adapter (12"); Series 4000 Super Plössl 26mm eyepiece; standard field tripod (7", 8", 10") or giant field tripod (12"); operating instructions.

MEADE LX200 EMC
MEADE LX200 EMC
MEADE LX200 EMC
MEADE LX200 EMC
8"
7"
10"
12"

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Prices shown are suggested U.S. mail-order retail prices.

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